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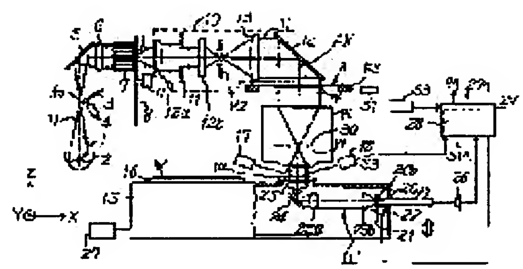
(54) PROJECTION ALIGNER

(57)Abstract:

PURPOSE: To measure the actual quantity of aberration so as to cope with the variation of the image forming characteristic of a projection exposing device by making light to incident to a mask by irradiating an opening pattern on a stage from the stage side and making reflected light from the mask to incident to a photoelectric conversion element through a projecting optical system and the opening pattern, and then, finding the quantity of aberration.



CONSTITUTION: A pattern plate provided on a stage 15 and having a prescribed opening pattern is irradiated from a stage 15 side while the stage 15 is moved in the direction of the optical axis AX. Then reflected light IL' from a mask R through a projecting optical system PL is received by means of a photoelectric conversion element 26. In addition, the quantity of aberration of the optical system PL is found by inputting the signal of a light receiving optical system 18 which measures the position of the stage 15 in the direction of the optical axis AX and a signal obtained from the element 26 to an aberration detecting system 28. Therefore, the quantity of aberration can be actually measured and the exposure can be performed in an aberration-corrected state or exposing operation can be performed in accordance with the aberration.

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CLAIMS

[Claim(s)]
[Claim 1] The illumination-light study system which irradiates the illumination light from the light source at a mask, and the projection optics which carries out image formation of the pattern of said mask on a sensitization substrate, In the projection aligner which has a movable stage in the direction of an optical axis of said projection optics, and the direction perpendicular to this optical axis while holding said sensitization substrate The criteria member which is prepared on said stage and has a predetermined opening pattern; Said opening pattern is illuminated from said stage side, moving said stage in the direction of an optical axis. The light which reached said mask through said projection optics, and was reflected with said mask Said projection optics and said opening pattern are minded. A light-receiving means to receive light, and a stage location measurement means to measure the location of said stage about the direction of the; aforementioned optical axis; the projection aligner characterized by having an amount operation means of aberration to calculate the amount of aberration of said projection optics from the signal wave form acquired from said photoelectrical detection means.
[Claim 2] The projection aligner according to claim 1 characterized by having an aberration amendment means to amend the aberration of said projection optics based on the result of said amount operation means of aberration.
[Claim 3] The projection aligner according to claim 1 characterized by having the exposure actuation control means which interrupts exposure actuation based on the result of said amount operation means of aberration.
[Claim 4] The projection aligner according to claim 1 characterized by having a stage location amendment means to amend the location of said direction of an optical axis of said sensitization substrate based on the result of said amount operation means of aberration.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] Especially this invention relates to the projection aligner used for manufacture of a semiconductor integrated circuit, a liquid crystal substrate, the thin film magnetic head, etc. about a projection aligner.
[0002]
[Description of the Prior Art] In recent years, in projection aligners, such as semi-conductor manufacture associated equipment, the very high image formation engine performance is demanded. The projection optics by which various kinds of aberration is amended by altitude is carried in this conventional kind of equipment. Usually, the check of the amount of aberration of projection optics was performed by using a special mask. The pattern of dedication for an aberration check is drawn on this special mask, the pattern of this dedication is exposed to the substrate for a test, and the amount check of aberration is performed by observing that exposure pattern under a microscope etc. after development. For example, the check of spherical aberration is performed by asking for the best focus location of the pattern of two or more different line breadth. Sequential positioning of the stage is carried out in the direction of an optical axis, in the direction of an optical axis, carrying out sequential migration, the pattern of two or more line breadth is exposed, and, specifically, the substrate for a test with which the sensitization agent was applied is developed. And as a result on a substrate, the pattern of each line breadth according to the distance of the direction of an optical axis from projection optics is formed. About each of the pattern of each line breadth formed on the substrate, with an electron microscope etc., line breadth is measured and the measured distance from the actual size of the line breadth of a pattern and the optical axis of projection optics is plotted. If the middle point (midpoint of the maximum location of a substrate location and the minimum location where predetermined line breadth is maintained) of the location of the substrate with which predetermined line breadth is maintained is determined as a best focus, the best focus location of each line breadth can be found from the curve of the plotted data. Here, when spherical aberration has occurred, a gap arises in the best focus location of each line breadth. The check of astigmatism should just search for the difference of the best focus location of the pattern with which directions differ. Next, when the example of the check of comatic aberration is shown, there is the approach of being plurality of carrying out continuously etc., being and seeing the difference of the line breadth of the both ends of the mark of line breadth.
[0003] Each aberration is searched for by the above approaches, and the image formation property of projection optics is optimized. For example, spacing of the lens element inside projection optics etc. is adjusted, and, finally each aberration is made below into an allowed value. However, each aberration always is not fixed and it may change with the temperature rises of the projection optics by projection optics absorbing a temperature change, atmospheric pressure change, and the illumination light. The temperature change of the projection optics especially by absorption of the illumination light may bring about aberration change which arises and cannot disregard temperature distribution in the lens element inside projection optics. In such a case, it is impossible to check the amount of aberration under exposure actuation by the above-mentioned approach.
[0004] Then, when the accumulated dose to the projection optics of exposure energy was calculated conventionally and the accumulated dose exceeded the fixed reference value, exposure actuation was suspended, and the method of not using it was proposed in the place where aberration got worse. Specifically, the relation between the amount of aberration generated beforehand and the heating value

accumulated in projection optics and the heat-absorptive property of projection optics are searched for. At the time of real exposure actuation, count which calculates the heating value serially accumulated to projection optics from the numerical model, mask permeability, and shutter keying signal of a heat-absorptive property which were searched for beforehand, and calculates the amount of aberration to generate is performed. When the amount of aberration exceeds an allowed value, if exposure actuation is stopped temporarily, it decreases, the amount of aberration also becomes below an allowed value, and the heating value accumulated to projection optics can perform exposure actuation again. Such an exposure approach is indicated by JP,63-291417,A.

[0005]

[Problem(s) to be Solved by the Invention] In the Prior art like the above, the calculated amount of aberration is a forecast to the last, and an actual aberration yield does not understand it. As a technique for increasing resolution especially in recent years, zona-orbicularis-like lighting or the oblique illumination from [which is indicated by JP,4-180612,A and JP,4-180613,A] plurality is proposed, and a phase shift mask which is further indicated by JP,62-50811,B is also proposed. When these techniques are used, the intensity distributions of the illumination light inside projection optics differ. For this reason, even when it is the same, the amounts of aberration generated by lighting conditions or the reticle also differ, and prediction of an aberration yield is difficult for lighting energy. Therefore, by the approach of expecting the conventional amount of aberration, the trouble that correspondence was impossible was in desired exposure actuation. This invention was made in view of such a conventional trouble, and enables measurement of the actual amount of aberration, and it aims at offering the equipment which can respond to fluctuation of an image formation property.

[0006]

[Means for Solving the Problem] The illumination-light study system which irradiates the illumination light from the light source (1) by this invention at a mask (R) for solution of the above-mentioned trouble (6, 7, 10), The projection optics which carries out image formation of the pattern (PA) of a mask on a sensitization substrate (W) (PL), In the projection aligner which has a movable stage (15) in the direction of an optical axis (AX) of projection optics, and the direction perpendicular to an optical axis while holding a sensitization substrate Are prepared on a stage, and an opening pattern is illuminated from a stage side, moving the criteria member (19) and; stage which have a predetermined opening pattern in the direction of an optical axis. The light which reached the mask through projection optics and was reflected with the mask Projection optics, a light-receiving means to receive light through an opening pattern, a stage location measurement means to measure the location of the stage about the direction of; optical axis, and an amount operation means of aberration to calculate the amount of aberration of projection optics from the signal wave form acquired from; photoelectrical detection means were established.

[0007]

[Function] In this invention, the predetermined opening pattern prepared on the stage is illuminated with the light of wavelength almost equal to exposure light from a stage side, and incidence of this illumination light is carried out to a mask through projection optics. And incidence of the illumination light reflected with the mask is carried out to a photodetector through projection optics and an opening pattern. The amount of aberration is calculated using the wave of the photoelectrical detecting signal from this photodetector. Since it is not necessary for ** to prepare the pattern of dedication on a mask while being able to skip procedures, such as exposure to a test substrate, development, and measurement, change of the amount of aberration can be serially known at the time of actual measurement. Consequently, it exposes in the condition that aberration has occurred and there is no un-arranging [of taking out a defective].

[0008]

[Example] Drawing 1 is the top view showing the rough configuration of the projection aligner by one example of this invention. In drawing, the light source 1 of an extra-high pressure mercury lamp etc. generates the illumination light (i line etc.) IL of a wavelength region which exposes a resist layer. As the light source for exposure, the higher harmonic of laser light sources, such as KrF besides the bright lines, such as a mercury lamp, and ArF excimer laser, or metal vapor laser, or an YAG laser may be used. It reflects in the ellipse mirror 2 and the illumination light IL is the 2nd focus f0. After condensing, incidence is carried out to a mirror 5 and a collimator lens 6, and the fly eye lens 7. The variable aperture 8 is formed in the injection side of a fly eye lens, and it is possible to change lighting conditions according to the class of reticle, or the periodicity of a pattern. Modification of this lighting condition is

performed by driving a variable aperture 8 by the motor 9.
[0009] Moreover, the 2nd focus f0 The shutter (for example, rotary shutter of four-sheet feather) 3 which performs closing of the optical path of the illumination light IL and disconnection by the motor 4 is arranged in near. Incidence of the illumination light IL which passed the variable aperture 8 is carried out to the adjustable blind 11 which restricts the lighting field on relay lenses 12a and 12b and Reticle R, and the optical system 10 containing a condenser lens 13, and it results in a mirror 14, and after being reflected caudad almost perpendicularly, it illuminates pattern space PA of Reticle R with an almost uniform illuminance here. Reticle R is laid on the reticle stage RS, and a reticle stage RS can move Reticle R slightly in the XY direction. Moreover, a reticle stage RS can move Reticle R slightly also to a Z direction (the direction of an optical axis) by the mechanical component 51, and the distance of Reticle R and projection optics PL can be changed, or it can lean Reticle R to a flat surface perpendicular to an optical axis AX. the illumination light IL which passed pattern space PA -- a both-sides tele cent -- carrying out incidence to the rucksack projection optics PL, projection optics PL forms the projection image of the circuit pattern of Reticle R on Wafer W. A resist layer is formed in a front face, Wafer W is held on the wafer stage 15 so that the front face may be mostly in agreement with the best image formation side, and heavy doubling ****** projection of the circuit pattern is carried out to one shot field on Wafer W. (Image formation of drawing 1 has not been carried out on Wafer W on account of explanation.) Vacuum adsorption is carried out at the wafer holder 16, and Wafer W is held on the wafer stage 15 through this holder 16. While being able to incline in the direction of arbitration and being able to move slightly in the direction of an optical axis (Z direction) to the best image formation side of projection optics PL, after consisting of step-and-repeat methods movable in the two-dimensional direction (X, the direction of Y) and completing imprint exposure of the reticle R to one shot field on Wafer W, stepping of the wafer stage 15 is carried out to the shot location of a degree.
[0010] Moreover, into drawing 1 , the focus system (wafer location detection system) of the oblique incidence method which consists of the exposure optical system 17 which supplies the image formation flux of light for forming the image of a pinhole or a slit towards the best image surface of projection optics PL from the direction of slant to an optical axis AX, and the light-receiving optical system 18 which receives the reflected light bundle in the front face of the wafer W of the image formation flux of light through a slit is prepared. About the configuration of this focus system, it is indicated by JP,60-168112,A, for example, the location of the direction (Z direction) over the image formation side on the front face of a wafer is detected, and the focus condition of Wafer W and projection optics PL is detected. In addition, in this example, the include angle of the parallel monotonous glass (plane parallel) which is not illustrated [which was beforehand prepared in the interior of the light-receiving optical system 18] is adjusted, and the calibration of a focus system is performed so that the best image formation side on a design may serve as zero-point criteria.
[0011] Next, an aberration detection system is explained. The pattern plate 19 is formed on the wafer stage 15, and on the pattern plate 19, as shown in drawing 2 , the predetermined opening pattern for aberration detection is drawn. Here, the pattern plate 19 is formed so that the front face of the pattern plate 19 may turn into a front face of Wafer W the same flat-surface top mostly. Beam-of-light IL' of the same wavelength field as the illumination light IL illuminates the pattern plate 19 from the wafer stage 15 side (lower part) through the dichotomy fiber 20, a variable aperture 21, relay lenses 23a and 23b, a mirror 24, and a condenser lens 25 mostly. Illumination-light IL' may branch the illumination light IL from the light source 1, and may install separately the light source which injects the light of the same wavelength as the illumination light IL. Image formation of the flux of light which came out from pattern opening of the pattern plate 19 is carried out to the pattern side PA of Reticle R through projection optics PL, and the reflected light carries out image formation on the pattern plate 19 through projection optics PL again. The flux of light which resulted in the pattern plate 19 passes opening of a pattern 19 again, passes along a condenser lens 25, a mirror 24, relay lenses 23a and 23b, a variable aperture 21, and the dichotomy fiber 20, and reaches an optoelectric transducer 26. The main control system 29 controls a motor 27, and moves the wafer stage 15 to a Z direction, and the aberration detection system 28 in the main control system 29 receives the signal S3 from an optoelectric transducer 26 to this and coincidence synchronizing with the signal from the light-receiving optical system 18 of a focal detection system. Thereby, the aberration detection system 28 obtains the output of the optoelectric transducer 26 to the location of the Z direction of the wafer stage 15. The main control system 29 also performs control of the motor 9 which drives a variable aperture 8, and the motor 22 which drives a variable aperture 21. In addition, the aberration detection system 28 can be used for focal location

detection (image formation side detection of projection optics PL) of a TTL (SURUZA lens) method, and can detect a focal location and aberration to coincidence. The main control system 29 controls the whole equipment besides control of a mechanical component 51 in generalization. Here, the opening pattern serves as combination of the pattern of the many directions like drawing 2 in consideration of astigmatism.

[0012] The principle in which a focal location can be found by the aberration detection system 28 is briefly explained using drawing 3 . Drawing 3 (a) is reflected with the mask R when Reticle R and the pattern plate 19 are shifted from the location [****] a little. When it is drawing showing the quantity of light distribution of the image of the opening pattern 19 by which image formation was again carried out through projection optics PL and drawing 3 (b) has Mask R and the pattern plate 19 in a location [****], It is drawing showing the quantity of light distribution of the image of the opening pattern 19 by which was reflected with Mask R and image formation was again carried out through projection optics PL, and drawing 3 (c) shows an example of the reference pattern plate 19. In drawing 3 (c), 19a is the protection-from-light section by the chromium vacuum evaporationo film etc.

[0013] When the reference pattern plate 19 and the pattern side of Reticle R are located in a location [****], as the intensity distribution of the image of the reference pattern plate 19 are shown in the distribution calcium of drawing 3 (b), almost in accordance with distribution of the light and darkness of reference pattern plate 19 the very thing, a great portion of light returns to the wafer stage 15 mostly through the transparency section of the reference pattern plate 19. On the other hand, when the reference pattern plate 19 is shifted from the pattern side of Reticle R, and the field [****] a little, as the image of the reference pattern plate 19 in which re-image formation was carried out by the reflected light from Reticle R is shown in the distribution Cb of drawing 3 (a), contrast falls. In this case, the slash section under distribution Cb of drawing 3 (a) cannot lap with protection-from-light section (nontransparent section) 19a of the reference pattern 19 of drawing 3 (c), and a reference pattern 19 cannot be passed, but the quantity of light which reaches an optoelectric transducer 26 decreases.

[0014] Drawing 4 is drawing showing the output value from the optoelectric transducer 26 at the time of setting an axis of ordinate as the output value of the detecting signal S3 from an optoelectric transducer 26, setting an axis of abscissa as the Z coordinate of the pattern plate 19, and moving the opening pattern 19 to a Z direction. It can ask for the location of the Z direction of the pattern plate 19 from the output from the light-receiving optical system 18 of a focal detection system. The time of Z coordinate Za when the output value S3 of an optoelectric transducer 26 is the largest having Reticle R and the pattern plate 19 in a location [**** / almost] (when it being peak value) is shown in drawing 4 , and, in the case of drawing 3 (b), it corresponds. Z coordinate Zb when being in the point that the output value from an optoelectric transducer 26 has fallen from peak value in drawing 4 shows the time of Reticle R and the pattern plate 19 being shifted from the location [****] a little, and, in the case of drawing 3 (a), corresponds.

[0015] When the reference pattern plate 19 comes to the focal location of projection optics PL as mentioned above, the detecting signal S3 outputted from an optoelectric transducer 26 serves as max. The signal wave form of a detecting signal S3 turns into a wave which falls in a concave on both sides of a peak by the interference phenomenon of the flux of light as shown in drawing 4 . Next, the configuration of the amendment means for amending an image formation condition is explained. In this example, it has composition which amends image formation properties (spherical aberration, comatic aberration, astigmatism, curvature of field, etc.) by driving the lens element of projection optics PL, or changing the pressure between lens elements. For this reason, a part of optical element of projection optics PL is movable. Furthermore, it has composition which makes adjustable the pressure between the optical elements of projection optics PL. Drawing 5 is drawing which explains the equipment of drawing 1 partially, and is drawing showing the device which makes adjustable the mechanical component of Reticle R, the mechanical component of the optical element of projection optics PL, and the pressure between optical elements. The supporter material 34 is fixed and the lens element 33 nearest to Reticle R is formed on the supporter material 36 through the driver element 35. The supporter material 36 is being fixed to the lens-barrel 52 of projection optics PL. A driver element 35 consists of driver elements 35a, 35b, and 35c (only 35a and 35b are illustrated in drawing 5) arranged in the location which it rotated 120 degrees at a time, respectively, and an independent control is possible for each driver element by the driver element control section 38. In addition, in drawing 5 , although the lens element 33 is shown as one lens, it can move slightly independently each lens group which shall be the lens element which consists of a lens group of three groups (or two groups), and constitutes the lens element 33 by the driver

element (un-illustrating).
[0016] Moreover, the supporter material 45 is fixed and the lens element 44 near about [of projection optics PL] pupil surface P1 is formed on the supporter material 47 through the driver element 46. The supporter material 47 is being fixed to the lens-barrel 52 of projection optics PL. A driver element 46 consists of driver elements 46a, 46b, and 46c (only 46a and 46b are illustrated in drawing 5) arranged in the location which it rotated 120 degrees at a time, respectively, and an independent control is possible for each driver element by the driver element control section 48. For example, the amount of displacement of the driver element according to the electrical potential difference or field given to a driver element shall be calculated beforehand, using an electrostriction component and magnetostrictor as driver elements 35 and 46. Although not illustrated here, suppose that a capacity type displacement sensor, a differential transformer, etc. are formed near the driver element as location detection equipment in consideration of the hysteresis nature of a driver element. Since the monitor of the location of the driver element corresponding to the electrical potential difference or field given to a driver element can be carried out by this, a highly precise drive is attained. Jogging of lens EREMEN 33 and 44 is performed so that spacing of a lens element may be changed, a lens element may be leaned to a flat surface perpendicular to an optical axis AX or a lens element may be moved in a flat surface perpendicular to an optical axis AX. About the configuration and actuation which drive such an optical element, it is indicated in detail by JP,4-134813,A.
[0017] In this example, by controlling the above-mentioned driver element 35 by the driver element control section 38, it has become movable about the lens element 33 near Reticle R, and the lens element 33 has chosen what the effect which gives image formation properties, such as comatic aberration and a curvature of field, tends to control greatly compared with other lens elements. Moreover, since the movable lens element 33 is considered as 3 group configurations, a successive range can be enlarged by moving a lens element, pressing down fluctuation of many of other aberration. Moreover, by controlling the above-mentioned driver element 46 by the driver element control section 48, it has become movable about the lens element 44 near a pupil surface P1, and the lens element 44 has chosen what the effect which gives spherical aberration tends to control greatly compared with other lens elements.
[0018] As for the lens elements 37 and 50, it is fixed to the lens-barrel 52, and the atmospheric-pressure adjusting device 39 adjusts the pressure of the air of the lens interior of a room between the lens element 33 and the lens element 37, and the atmospheric-pressure adjusting device 49 adjusts the pressure of the air of the lens interior of a room between the lens element 44 and the ENZU element 50. Thus, changing the image formation property of projection optics and amending aberration etc. is indicated by JP,60-78454,A by changing the pressure of the air section between lens elements.
[0019] Moreover, near the pupil surface P1, the cylindrical lenses 40 and 41 of two sheets are formed, and astigmatism is controlled by rotating these relatively by mechanical components 42 and 43, or changing spacing of a lens. Cylindrical lenses 40 and 41 are arranged in the direction which intersected perpendicularly mutually, and change the refractive index in X and the direction of Y by rotating these relatively. And the astigmatism component which was made to rotate these lenses relatively and was generated with other lens elements so that X and Y component might negate each other is removed. The main control system 29 controls these driver element control sections 38 and 48, mechanical components 42 and 43, and the atmospheric-pressure adjusting devices 39 and 49.
[0020] Next, the above-mentioned variable aperture 8 and the variable aperture 30 within projection optics PL are explained briefly. Generally as a numeric value which shows the property of an illumination system, the sigma value showing the numerical aperture NA of projection optics and the coherency of the illumination light is used. Numerical aperture and a sigma value are explained with reference to drawing 6 . The greatest include-angle thetaR which can pass the flux of light from the reticle R side of projection optics PL in drawing 6 since the aperture diaphragm 30 is formed in the pupil surface P1 of projection optics PL, i.e., the Fourier transform side of a mask pattern PA, And the greatest include-angle thetaW of the flux of light which carries out an incident light to Wafer W (pattern plate 19) side from projection optics PL It is restricted to the predetermined value. the numerical aperture PL of projection optics PL -- sinthetaW it is -- if a projection scale factor is set to 1/m -- sinthetaR =sinthetaW It has the relation of /m.
[0021]
[Equation 1] sigma IL=sinthetaIL/sinthetaR Although resolution improves so that numerical aperture NA is large to general = m-sinthetaIL/sinthetaW, the depth of focus becomes shallow. Although the edge of a pattern will fade on the other hand if the edge of a pattern will be emphasized if a sigma value

becomes small, and a sigma value is large since the coherency of the exposure light IL becomes good so that a sigma value is small, it comes to be able to perform resolving of a thinner pattern. Therefore, change of a sigma value changes the illumination distribution in the pupil surface P1 of projection optics PL.

[0022] As mentioned above, according to lighting conditions, the temperature distribution inside projection optics PL change, and this means that the aberration generated by the temperature rise differs. As shown in a rotor plate 8 at drawing 7 , specifically, six kinds of aperture diaphragms 132-137 are formed by the equiangular distance. Among these aperture diaphragms, the circular aperture diaphragms 132 and 133 have the usual circular openings 132a and 133a of a diameter different, respectively, and the zona-orbicularis aperture diaphragm 134 has zona-orbicularis-like opening 134a. Moreover, the aperture diaphragms 135 and 136 for two or more oblique illuminations have one pair of minute openings 135a and 135b arranged in the direction which intersects perpendicularly mutually, respectively, and 136a and 136b, and the aperture diaphragm 137 for two or more oblique illuminations has four minute openings 137a-137d arranged centering on an optical axis at the equal distance.

[0023] In addition, when using the drawing 135,136,137 of a rotor plate 8, it is desirable to set up so that the sigma value of the illumination-light bundle from each opening may become 0.1 to about 0.3. Furthermore, it is desirable to constitute so that it may extract according to whenever [of a reticle pattern / detailed] (pitch etc.) and the location of each opening in each of 135-137 can be tuned finely. Furthermore, since the illuminance homogeneity on a reticle or a wafer can worsen when using diaphragms 133-137, what each element of the fly eye lens 7 is made fine for (the cross section is made small) is desirable. Still more nearly another integrator (a fly eye mold or rod mold) is added, and it is good also as two steps of integrator structures.

[0024] Moreover, at the time of use of diaphragms 135-137, since the quantity of light loss is large, it is good to constitute using optical dividers, such as an optical fiber and multiple prism, so that exposure light may be led to each opening on a diaphragm. Moreover, especially as an example of the selection criterion of the aperture diaphragm of a rotor plate 8, to a detailed pattern, using an aperture diaphragm 135,136,137 (what is necessary is just to choose these three proper use according to the periodicity of a reticle pattern), when line breadth is not severe, an aperture diaphragm 133 (or an aperture diaphragm 141 may be used) is used for a phase shift reticle using an aperture diaphragm 132. The aperture diaphragm 137 of an aperture diaphragm 135 is effective to a two-dimensional pattern to the periodic pattern arranged in the direction of X, and the periodic pattern with which the aperture diaphragm 36 was arranged in the direction of Y.

[0025] It is indicated by JP,4-180612,A, JP,4-180613,A, JP,4-225514,A, etc. about the optimal location of opening of aperture diaphragms 135, 136, and 137. For example, when it is an effective aperture diaphragm and its attention is paid to one opening 137a about an aperture diaphragm 137 to a two-dimensional period pattern, an aperture diaphragm 137 defines the location of opening 137a so that either of the primary [**] diffracted lights, either of the primary [**] diffracted lights by the pattern of the direction of Y, and the zero-order diffracted light by the pattern of the direction of X may serve as the equal distance from an optical axis on the pupil surface P1 of projection optics PL. If a location is defined on conditions with the same said of other openings (137b-137d), each opening (137a-137d) will be set to the location which serves as the equal distance from an optical axis after all.

[0026] When searching for aberration from the signal wave form from an optoelectric transducer 26, in order to make in agreement here two quantity of light distribution in case the illumination light IL from the illumination-light study system 10 and illumination-light IL' which passed the pattern plate 19 pass projection optics PL, It is necessary to make illumination distribution in the pupil surface P1 of the projection optics PL by the illumination light from a fiber 20 equal to the illumination distribution in the pupil surface P1 of the projection optics PL by the illumination light injected from the fly eye lens 7. What is necessary is to consider as six kinds of aperture diaphragms [**** / the aperture diaphragm (132-137) which shows the aperture diaphragm which formed the rotor plate 21 near the edge / in collaboration / 20of fiber bundle b, and was prepared in the rotor plate 21 to drawing 7], and just to choose the aperture diaphragm of a rotor plate 21 there according to the aperture diaphragm of a rotor plate 8.

[0027] Next, how to search for aberration from the signal wave form from an optoelectric transducer 26 is explained. From the wave of a photoelectrical detecting signal, the principle asked for each amount of aberration can be explained as follows. In order to improve resolving of specific pattern line breadth, when NA of the source of the illumination light is made small, it becomes what the flux of light inclines

toward the center section of the lens of projection optics (it gathers) (when it considers as partial coherent illumination). When there is a mask pattern, the diffracted light reaches around a lens, but since the reinforcement of the diffracted lights other than zero-order is generally weaker than the zero-order diffracted light, the inclination for the flux of light to incline toward the center section of the lens does not change.
[0028] Then, when very slight heat absorption exists in the lens which constitutes projection optics, if light is irradiated at projection optics, generation of heat will take place according to the quantity of light which penetrates a lens. When a lens generates heat, in many cases, a refractive index increases with expansion (however, there is also a case of reduction by generation of heat). That is, in the convex lens which has forward power (refractive power) by generation of heat, the power of a lens center section increases compared with a periphery according to deformation of a lens center section and the effectiveness of a distribution refractive-index lens. This situation is shown in drawing 8 , the condition that drawing 8 (a) does not have spherical aberration is shown, and drawing 8 (b) shows the condition (condition which spherical aberration has generated) of having carried out superfluous amendment of the spherical aberration. When spherical aberration is amended by the initial state like drawing 8 (a), as the slash of drawing 8 (b) shows after the exposure of light, the power of the center section of the lens 32 increases, and since it will be in the condition that only M carried out superfluous amendment of the spherical aberration, a focal location is changed (it ****s out of a focus).
[0029] Drawing 9 is drawing showing the output signal S3 from a photodetector 26, like drawing 4 , an axis of ordinate shows signal strength and an axis of abscissa shows the location of the Z direction of the pattern plate 19. The output signal S3 in case drawing 9 (a) does not have spherical aberration is shown, and drawing 9 (b) shows the output signal S3 when spherical aberration has occurred. When signal detection by focal detection equipment is performed in this condition, the signal which spread along the direction of an optical axis as shown in drawing 9 (b) will be acquired. In the condition that there is no spherical aberration, the diameter of the flux of light turns into a symmetrical diameter in accordance with an optical axis. the half-value width of the signal wave form shown in drawing 9 (a) -- W1 it is -- half-value width W1 Z location Z0 in a core and peak value It is in agreement. That is, the signal wave form of drawing 9 (a) is a symmetrical signal wave form about peak value.
[0030] On the other hand, in drawing 9 (b), the diameter of the flux of light in that order meets an optical axis by overspherical-aberration amendment on the basis of the circle of least confusion location (drawing 9 (b) Z1), and it becomes an unsymmetrical diameter. Therefore, distribution of the signal quantity of light is Z1 to the appearance shown in drawing 9 (b). It is related and becomes unsymmetrical. The above is the process in which a lens has deformation and a distribution refractive index asymmetrically by optical exposure, and a focal detecting signal is distorted. In addition, although a concave lens is also contained in a lens, since it is a convex lens as a whole, the above explanation is qualitatively applied. In that case, the amount of spherical aberration (based on superfluous amendment) to generate is followed, and it is the half-value width w2 of a signal. Half-value width W1 Since it compares and becomes large, it is half-value width w2. It can measure and the amount of spherical aberration can be measured. Moreover, since the asymmetry of a signal also increases according to the amount of spherical aberration, it is also possible to measure the amount of spherical aberration from the asymmetry of a signal. Specifically, it is the bottom value I0 on the left-hand side of a signal wave form. Peak value P0 of a signal wave form It inserts and is the right-hand side bottom value I1. Output difference I2 Measurement of spherical aberration is possible also by measuring. moreover, a bottom value -- the bottom value I0 and I1 not only -- two or more bottom value as a high order component -- peak value P0 It inserts and appears in right and left. The amount of spherical aberration can be measured to high degree of accuracy by comparing the bottom value of these right and left over two or more sets. In addition, change of the half-value width W of a signal, the relation of the yield of spherical aberration, or the relation of the yield of the difference and spherical aberration of a bottom value is called for from performing proof print etc. beforehand. This relation shall be inputted into the main control system 29 by the input means 53, and shall be memorized by the memory in the main control system 29. Moreover, it asks by measuring the focus location within the image surface using opening pattern 19a of the many directions as shown in drawing 2 also about a curvature of field.
[0031] The above case explained the case where the flux of light shone upon a projection lens at axial symmetry. However, when the pattern of an one direction is in a mask, the diffracted light will occur not in axial symmetry but in asymmetry. Therefore, the case where deformation of the lens by exposure takes place to a shaft asymmetrically can be considered. That is, astigmatism (astigmatic difference)

arises by exposure. In this case, it is made to perform focal location measurement in at least two directions (for them to be the radiation direction and a direction perpendicular to it centering on the optical axis of projection optics) which arranged pattern 19a of the projection pattern plate 19 in the same direction, and are different in that direction. Then, it is the peak location Z0 shown in drawing 7 when there was the astigmatic difference. Values differ in each direction and can measure the astigmatic difference by measuring the difference.
[0032] Moreover, although the above example explained spherical aberration, a curvature of field, and astigmatism, comatic aberration etc. is detectable with an aberration detection system. That is, what is necessary is just to detect that the focus location and detecting signal of the direction of an optical axis have breadth according to comatic aberration. As specifically shown in drawing 10 , let opening pattern 19a be the pattern which has the two directions of the pattern (S image) of a radial, and a pattern (M image) perpendicular to it centering on the optical axis AX of projection optics PL. And comatic aberration is measurable by comparing the unsymmetrical component of the signal acquired from each pattern. Drawing 11 shows the signal wave form acquired from the pattern shown in drawing 10 , drawing 11 (a) shows the signal acquired from the pattern (S image) of the radiation direction, and drawing 11 (b) shows the signal acquired from the pattern (M image) of a direction perpendicular to the radiation direction here. In drawing 11 , the case where the radiation direction component (S image) is unsymmetrical is shown for comatic aberration, the aberration detection system 28 compares the unsymmetrical component of these two signals, and the amount of comatic aberration is measured. Asymmetric detection uses half-value width W like the case of detection of the spherical aberration explained using drawing 9 , and is the half-value width W1 of two signals. W2 What is necessary is to compare or just to ask by comparing two bottom values which sandwiched peak value etc. The relation between the difference of an unsymmetrical component and the amount of comatic aberration is called for from performing proof print etc. beforehand. This relation shall be inputted into the main control system 29 by the input means 53, and shall be memorized by the memory in the main control system 29.
[0033] In addition, in case spherical aberration and comatic aberration are measured, the measurement by the 2-way from which pattern 19a differed may be equipped with two or more focal measurement systems shown in drawing 1 , prepares the mark of a direction which is different in pattern 19a, and may take the approach of switching and choosing them by diaphragm etc. Next, the measurement approach of the image formation property of the projection optics PL, such as spherical aberration in this example and comatic aberration, is described. It moves by the motor 27 on the wafer stage 15 so that the core of opening 19a on the criteria member 19 may come on the optical axis AX of projection optics. this -- the time -- coincidence -- a motor -- 27 -- driving -- a wafer -- a stage -- 15 -- projection optics -- PL -- a design -- a top -- best -- a focus -- a location (the best image formation side) -- ** -- considering -- having -- a location -- from -- expecting -- having -- a focus -- fluctuation -- an amount (the amount of fluctuation of an image formation property) -- several -- a time -- about -- lowering -- or -- or -- raising -- it grazes. this -- for example, about (2 and DOF) 2 times of the depth of focus (**DOF) -- lowering -- or -- or you may carry out whether it raises. Moreover, the rear face (pattern side) of Reticle R is illuminated through opening 19 and projection optics PL to coincidence. After the illumination light reflected from Reticle R passes along projection optics PL and opening 19 again, incidence of it is carried out to a photodetector 26 through a lens 25, a mirror 24, a lens 23, and an optical fiber 20. about 2 times of the amount of focal fluctuation expected which mentioned the wafer stage 15 above up (or lower part) in this condition after that -- scanning . At this time, the aberration detecting element 28 samples and carries out A/D conversion of the output of a photodetector 26, and the output of the light-receiving optical system 18 of a focus system to coincidence at every [of the wafer stage 15] unit movement magnitude (for example, 0.02 micrometers), and relation as shown in drawing 4 is obtained. And based on the signal wave form from an optoelectric transducer 26, aberration is measured from the symmetric property etc. like the above-mentioned.
[0034] Next, the amendment approach of the aberration of the projection optics PL by this example is explained. When the amount of aberration is detected as mentioned above, aberration can be amended by adjusting a projection lens etc.
[Amendment of spherical aberration] The amendment approach of spherical aberration is explained. Amendment of spherical aberration is performed by changing lens spacing of the lens elements 44 and 50 (drawing 5) of pupil P2 near [projection optics PL]. Moreover, it may be made to perform aberration amendment by changing the pressure of the air of the lens interior of a room between the lens element 44 and 50 with the atmospheric-pressure adjustment 49.

[Amendment of comatic aberration and a curvature of field] Amendment of comatic aberration or a curvature of field is performed by changing spacing of the lens which is separated from a pupil P2. In this example, aberration amendment is performed by moving the lens element 33 and inclining. Moreover, amendment of comatic aberration may be made to perform the pressure of the air of the lens interior of a room between the lens elements 33 and 37 with the atmospheric-pressure adjusting device 39.
[Amendment of astigmatism] Amendment of astigmatism is performed by rotating relatively the cylindrical lenses 40 and 41 of two sheets prepared in the lens. Moreover, you may make it change spacing of the cylindrical lens of two sheets.
[0035] As mentioned above, each aberration amendment is carried out to other aberration by effect choosing few lens elements. Moreover, it is made to perform measurement and amendment of such aberration by modification of each lighting conditions being interlocked with. Here, when achromatism of the projection lens is carried out by plurality or a certain wavelength range, it is possible to measure many aberration which enabled the exposure on two or more wavelength from the focus system (exposure optical system 17) of drawing 1 , performed measurement using two or more wavelength independently respectively, and carried out signal machine ****** **** from the optoelectric transducer 26. In that case, a bunt pass filter is inserted in the light source section, and they are exchanged so that two or more wavelength may be penetrated, respectively.
[0036] Moreover, although possibility that the image surface will move up and down is also considered by the drive of the lens elements 33 and 44, Wafer W will be set to the best image surface whenever it gives offset to an output value from the light-receiving optical system 18 of a focus system according to this variation. Next, the exposure sequence which interrupts exposure is explained based on the result from the aberration detection system 28.
[0037] Half-value width w2 of the signal from an optoelectric transducer 26 If it becomes above large to some extent, since an image formation condition will get worse, it is w2 beforehand. When the upper limit is defined and it is exceeded, making it interrupt exposure actuation is also thought of. Aberration conditions get worse by absorption of the illumination light of projection optics PL as mentioned above. For this reason, aberration is checked with an aberration measurement means at the time of exposure working, for example, wafer exchange, and it judges whether it has exceeded to the allowed value beforehand calculated by the experiment or the simulation. It is desirable to perform the calibration of a focal location to coincidence, of course at this time. When it is over the allowed value, the aberration detection system 28 generates warning in the main control system 29, and the main control system 29 stops exposure actuation. this condition -- being periodical (every [for example,] 30sec(s)) -- it judges whether aberration was measured and it is over the allowed value. The heating value accumulated in projection optics PL by interruption of exposure actuation is emitted outside, in the order which became below the allowed value, the aberration detection system 28 starts the signal of Exposure O.K., and delivery and the Maine controller start exposure actuation again at the main control system 29. Since the above-mentioned allowed values differ by the line breadth of the exposed reticle pattern, a pattern species, etc., conditions are beforehand inputted into the main control system 29 with the input means 53, and making permissive conditions adjustable is also considered. Moreover, measurement spacing of aberration is not necessarily limited for every fixed spacing, and immediately after the exposure of the illumination light IL, measurement spacing is lengthened, and measurement spacing is shortened as irradiation time becomes long. Moreover, a pattern 19 may be made exchangeable and you may make it in agreement with a real exposure pattern.
[0038] Next, the approach of amending the calibration of the focal location which can be found by the aberration detection system is explained. Focal location measurement can be performed using the reference pattern plate 19 as mentioned above. usually, the pattern exposed although the pattern of the pattern plate 19 is made in agreement with the actually exposed line breadth -- size -- it is various and is not necessarily in agreement. In this case, when spherical aberration occurs by illumination-light absorption, a focal location changes with line breadth and there is a problem that the result of focal location measurement is not in agreement in the focal location of a real exposure pattern. Here, if exposure line breadth and the amount of spherical aberration are known, it can amend. About line breadth, it writes in by the approach of inputting, for example from a keyboard etc., or the reticle bar code, and how to read can be considered. What is necessary is to ask for relation by measurement or the simulation beforehand about spherical aberration and the amount of focal location gaps, and just to memorize in the form of a table or a formula. Or the method of waiting for the effect which the amount

of spherical aberration does to focal detection to prepare the allowed value which can be disregarded enough, and not to perform focal location measurement in more than an allowed value, for example, to interrupt exposure actuation, and to cool projection optics enough is also considered.
[0039] Thus, since the aberration of projection optics PL is actually measurable based on the signal wave form from an optoelectric transducer 26, the time and effort of exposing a pattern using a special mask is not taken, but the amount of aberration is simply known at the time of actual equipment use. Based on this surveyed aberration, termination of the exposure actuation at the time of aberration generating, error correction of the focal detection system by the amount of aberration, or amendment of the real time of aberration can be performed.
[0040] As drawing 5 explained, although [the above-mentioned example] it has the devices 39 and 49 in which the pressure of the air chamber between lens elements is changed, and the devices 38, 48, 42, and 43 in which spacing of a lens element is changed, it is necessary to have no aberration amendment devices. For example, you may make it have the devices 39 and 49 in which a pressure is changed, or the devices 38, 48, 42, and 43 in which spacing of a lens element is changed. Moreover, it is also effective to have only these parts to specific aberration amendment.
[0041]
[Effect] Since the amount of aberration can be surveyed as mentioned above according to this invention, where aberration is amended, it can expose or exposure actuation according to aberration can be performed. Moreover, since the amount of aberration can be surveyed, even when the amount of aberration generated [oblique illuminations / a phase shift reticle, / two or more] cannot be predicted, the exposure according to the aberration to generate is attained.

[Translation done.]

* NOTICES *

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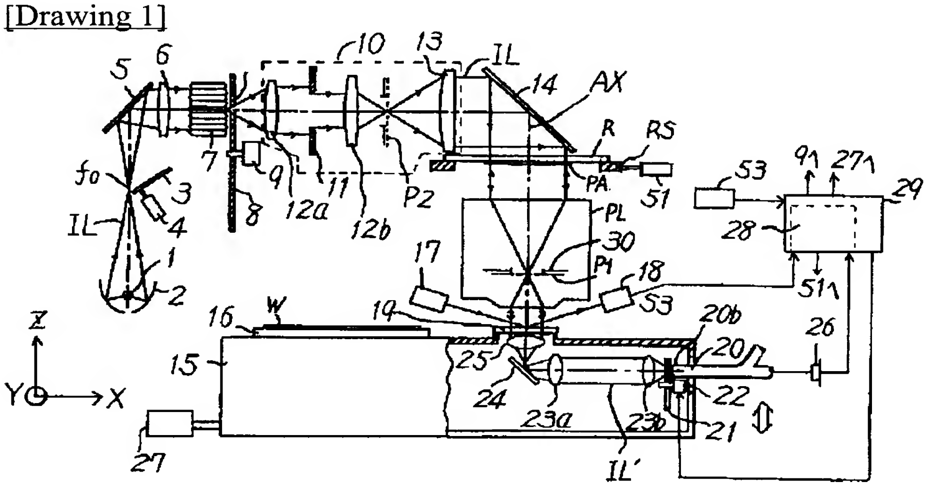
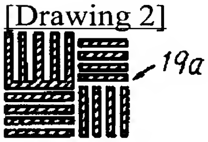
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

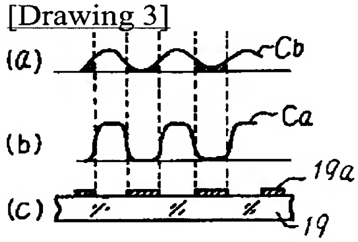
[Drawing 1]



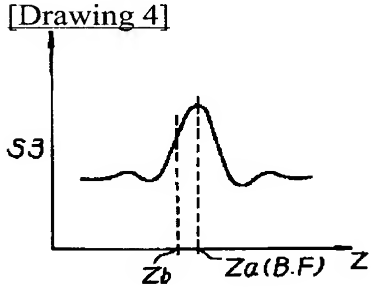
[Drawing 2]



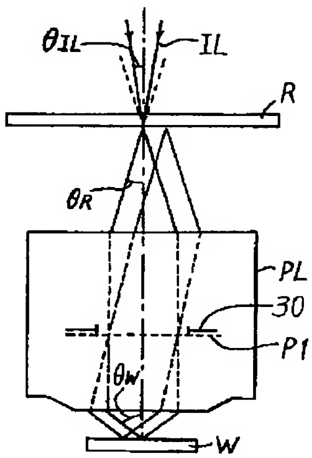
[Drawing 3]



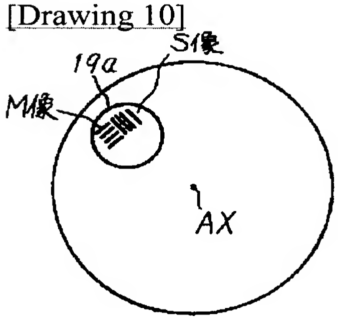
[Drawing 4]



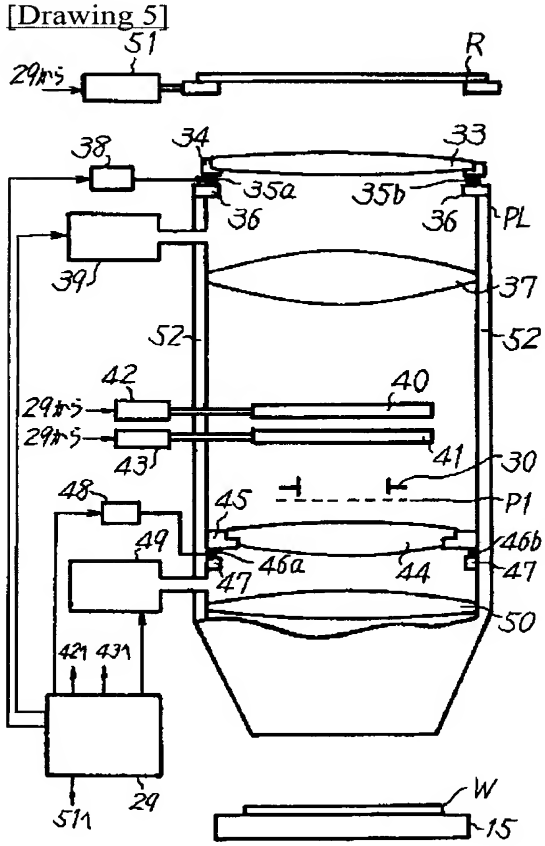
[Drawing 6]



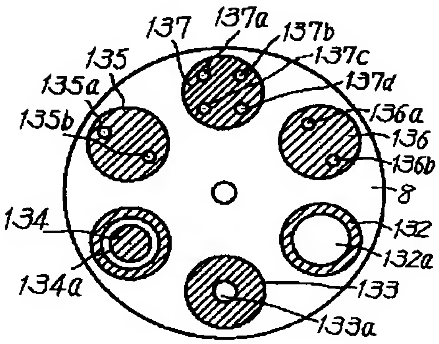
[Drawing 10]



[Drawing 5]

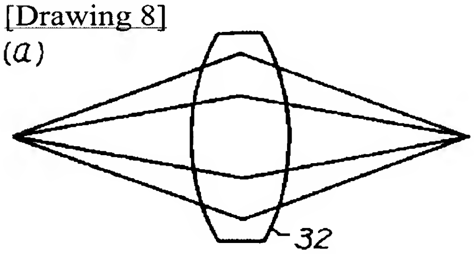


[Drawing 7]

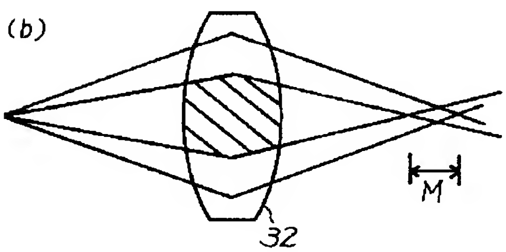


[Drawing 8]

(a)

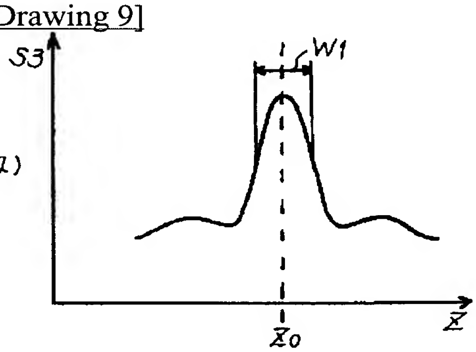


(b)

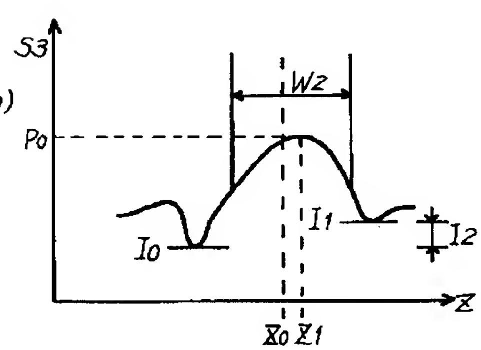


[Drawing 9]

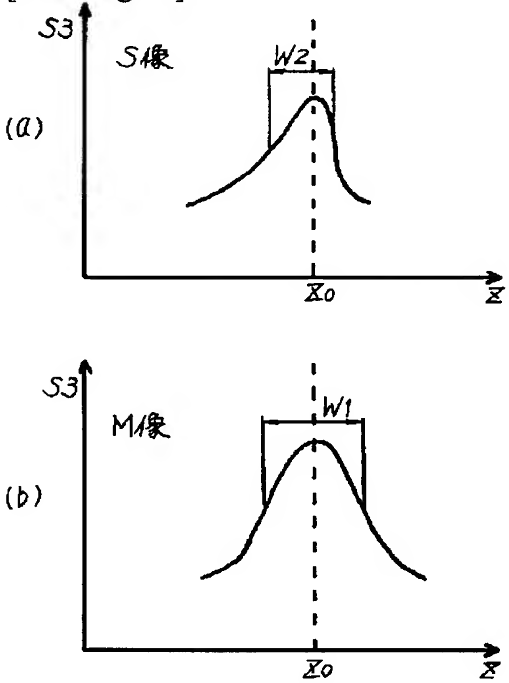
(a)



(b)



[Drawing 11]



[Translation done.]

CORRECTION OR AMENDMENT

[Kind of official gazette] Printing of amendment by the convention of 2 of Article 17 of Patent Law
[Section partition] The 2nd partition of the 7th section
[Publication date] March 16, Heisei 13 (2001. 3.16)

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[Date of Publication] March 25, Heisei 6 (1994. 3.25)
[Annual volume number] Open patent official report 6-848
[Application number] Japanese Patent Application No. 4-237162
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H01L  21/027
G02B  26/06
G02F   1/01
G03F   7/207
G11B   5/31
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[FI]

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H01L  21/30    311 N
G02B  26/06
G02F   1/01
G03F   7/207       H
G11B   5/31        M
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[Procedure revision]
[Filing Date] January 12, Heisei 12 (2000. 1.12)
[Procedure amendment 1]
[Document to be Amended] Specification
[Item(s) to be Amended] The name of invention
[Method of Amendment] Modification
[Proposed Amendment]
[Title of the Invention] A projection aligner and an approach
[Procedure amendment 2]
[Document to be Amended] Specification
[Item(s) to be Amended] Claim
[Method of Amendment] Modification
[Proposed Amendment]
[Claim(s)]
[Claim 1] In the illumination-light study system which irradiates the illumination light from the light source at a mask, the projection optics which carries out image formation of the pattern of said mask on a sensitization substrate, and the projection aligner which has a movable stage in the direction of an optical axis of said projection optics, and the direction perpendicular to this optical axis while holding said sensitization substrate,
Criteria member which is prepared on said stage and has a predetermined opening pattern;
A light-receiving means to receive the light which illuminated said opening pattern from said stage side,

moving said stage in the direction of an optical axis, reached said mask through said projection optics, and was reflected with said mask through said projection optics and said opening pattern;
A stage location measurement means to measure the location of said stage about said direction of an optical axis;
The projection aligner characterized by having an amount operation means of aberration to calculate the amount of aberration of said projection optics from the signal wave form acquired from said photoelectrical detection means.
[Claim 2] The projection aligner according to claim 1 characterized by having an aberration amendment means to amend the aberration of said projection optics based on the result of said amount operation means of aberration.
[Claim 3] The projection aligner according to claim 1 characterized by having the exposure actuation control means which interrupts exposure actuation based on the result of said amount operation means of aberration.
[Claim 4] The projection aligner according to claim 1 characterized by having a stage location amendment means to amend the location of said direction of an optical axis of said sensitization substrate based on the result of said amount operation means of aberration.
[Claim 5] It is the projection aligner which exposes said substrate by projecting the pattern of a mask on a substrate through projection optics,
Said projection optics is arranged between the 1st [which was fixed to the lens-barrel], and 2nd fixed lens elements, the 1st [said] fixed lens element, and said 2nd fixed lens element, and it has a movable moving lens element to said lens-barrel,
The driving means to which said moving lens element is moved,
A detection means to detect the spherical aberration of said projection optics,
The projection aligner characterized by having the control means which controls said driving means based on the spherical aberration detected by said detection means, and moves said moving lens element.
[Claim 6] While illuminating said mask by exposure light, it has further the illumination system which can change lighting conditions,
Said detection means is a projection aligner according to claim 5 characterized by for modification of said lighting conditions being interlocked with and detecting said spherical aberration.
[Claim 7] Said illumination system is a projection aligner according to claim 6 characterized by having the modification member which changes the illumination distribution in the pupil surface of said projection optics.
[Claim 8] Said detection means is a projection aligner given in any 1 term of claims 5-7 characterized by the ability to also detect aberration other than the spherical aberration of said projection optics.
[Claim 9] The positional information in the direction of an optical axis of said projection optics of said substrate is detected, and it has further a focus means to make said substrate and best image formation side of said projection optics agree according to this detection result,
Said control means is a projection aligner given in any 1 term of claims 5-8 characterized by giving the offset according to migration of said moving lens element to said focus means.
[Claim 10] It is the projection exposure approach which exposes said substrate by projecting the pattern of a mask on a substrate through projection optics,
The projection exposure approach characterized by being arranged between the 1st [which detected the spherical aberration of said projection optics and was fixed to the lens-barrel of said projection optics based on the detected spherical aberration], and 2nd fixed lens elements, and moving a movable moving lens element to said lens-barrel.
[Procedure amendment 3]
[Document to be Amended] Specification
[Item(s) to be Amended] 0005
[Method of Amendment] Modification
[Proposed Amendment]
[0005]
[Problem(s) to be Solved by the Invention] In the Prior art like the above, the calculated amount of aberration is a forecast to the last, and an actual aberration yield does not understand it. As a technique for increasing resolution especially in recent years, zona-orbicularis-like lighting or the oblique illumination from [which is indicated by JP,4-180612,A and JP,4-180613,A] plurality is proposed, and

a phase shift mask which is further indicated by JP,62-50811,B is also proposed. When these techniques are used, the intensity distributions of the illumination light inside projection optics differ. For this reason, even when it is the same, the amounts of aberration generated by lighting conditions or the reticle also differ, and prediction of an aberration yield is difficult for lighting energy. Therefore, by the approach of expecting the conventional amount of aberration, the trouble that correspondence was impossible was in desired exposure actuation. This invention was made in view of such a conventional trouble, and enables measurement of the actual amount of aberration, and it aims at offering the equipment and the approach of an image formation property which can respond to fluctuation.
[Procedure amendment 4]
[Document to be Amended] Specification
[Item(s) to be Amended] 0006
[Method of Amendment] Modification
[Proposed Amendment]
[0006]
[Means for Solving the Problem] The illumination-light study system which irradiates the illumination light from the light source (1) by this invention at a mask (R) for solution of the above-mentioned trouble (6, 7, 10), The projection optics which carries out image formation of the pattern (PA) of a mask on a sensitization substrate (W) (PL), In the projection aligner which has a movable stage (15) in the direction of an optical axis (AX) of projection optics, and the direction perpendicular to an optical axis while holding a sensitization substrate Are prepared on a stage, and an opening pattern is illuminated from a stage side, moving the criteria member (19) and; stage which have a predetermined opening pattern in the direction of an optical axis. The light which reached the mask through projection optics and was reflected with the mask Projection optics, a light-receiving means to receive light through an opening pattern, a stage location measurement means to measure the location of the stage about the direction of; optical axis, and an amount operation means of aberration to calculate the amount of aberration of projection optics from the signal wave form acquired from; photoelectrical detection means were established. Moreover, this invention is characterized by the projection aligner which exposes a substrate possessing the following by projecting the pattern of a mask on a substrate through projection optics. Projection optics is the 1st and 2nd fixed lens elements (37 50) fixed to the lens-barrel (52). The driving means to which it is arranged between the 1st fixed lens (37) and the 2nd fixed lens (50), and has the movable moving lens element (44) to the lens-barrel, and the moving lens element is moved (48) A detection means to detect the spherical aberration of projection optics (26 20- 28) The control means which controls a driving means based on the spherical aberration detected by the detection means, and moves a moving lens element (29) Furthermore, this invention is the projection exposure approach which exposes a substrate by projecting the pattern of a mask on a substrate through projection optics, and the spherical aberration of projection optics is detected and it is characterized by being arranged between the 1st [which was fixed to the lens-barrel of projection optics], and 2nd fixed lens elements, and moving a movable moving lens element to a lens-barrel based on the detected spherical aberration.
[Procedure amendment 5]
[Document to be Amended] Specification
[Item(s) to be Amended] 0041
[Method of Amendment] Modification
[Proposed Amendment]
[0041]
[Effect] Since the amount of aberration can be surveyed as mentioned above according to this invention, where aberration is amended, it can expose or exposure actuation according to aberration can be performed. Moreover, since the amount of aberration can be surveyed, even when the amount of aberration generated [oblique illuminations / a phase shift reticle, / two or more] cannot be predicted, the exposure according to the aberration to generate is attained. Furthermore, accurate spherical-aberration amendment is attained by moving the lens element which surveys spherical aberration and affects spherical aberration.

[Translation done.]

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(43)公開日　平成６年(1994)３月25日

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Ｇ０２Ｂ　26/06		9226－2K		
Ｇ０２Ｆ　1/01				
Ｇ０３Ｆ　7/207	Ｈ	9122－2H		
		7352－4M	Ｈ０１Ｌ　21／30　　３１１　Ｎ	

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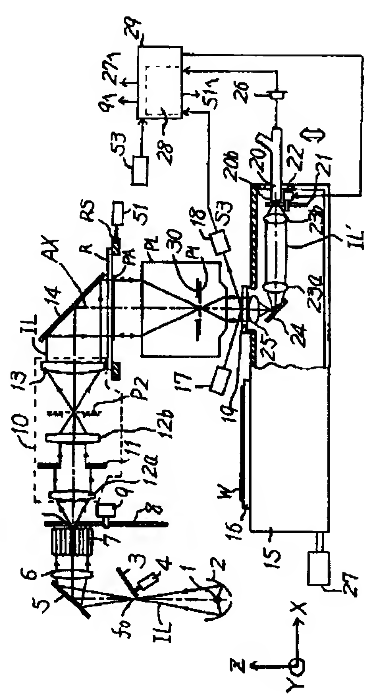
(54)【発明の名称】　投影露光装置

(57)【要約】

【目的】　投影光学系の諸収差を計測する。

【構成】　開口パターン１９ａをステージ１５側から照明し、照明光ＩＬ’はより投影光学系ＰＬを介してレチクルＲに到達する。レチクルＲで反射された照明光ＩＬ’は投影光学系ＰＬと開口パターン１９ａとを介して光電変換素子２６に入射する。光電変換素子２６からの信号を合焦系の受光光学系１８からの信号とともに収差検出系２８に取り込み、光電変換素子２６からの信号波形に基づいて投影光学系ＰＬの収差を測定する。



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【特許請求の範囲】

【請求項1】　光源からの照明光をマスクに照射する照明光学系と、前記マスクのパターンを感光基板上に結像する投影光学系と、前記感光基板を保持するとともに前記投影光学系の光軸方向及び該光軸と垂直な方向に移動可能なステージとを有する投影露光装置において、
前記ステージ上に設けられ、所定の開口パターンを有する基準部材と；前記ステージを光軸方向に移動させながら前記開口パターンを前記ステージ側より照明し、前記投影光学系を介して前記マスクに到達し、前記マスクで反射された光を、前記投影光学系と前記開口パターンを介して受光する受光手段と；前記光軸方向に関する前記ステージの位置を計測するステージ位置計測手段と；前記光電検出手段から得られる信号波形より前記投影光学系の収差量を求める収差量演算手段とを有することを特徴とする投影露光装置。

【請求項2】　前記収差量演算手段の結果に基づいて前記投影光学系の収差を補正する収差補正手段を有することを特徴とする請求項1記載の投影露光装置。

【請求項3】　前記収差量演算手段の結果に基づいて露光動作を中断させる露光動作制御手段を有することを特徴とする請求項1記載の投影露光装置。

【請求項4】　前記収差量演算手段の結果に基づいて前記感光基板の前記光軸方向の位置を補正するステージ位置補正手段を有することを特徴とする請求項1記載の投影露光装置。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は投影露光装置に関し、特に半導体集積回路、液晶基板、薄膜磁気ヘッド等の製造に用いられる投影露光装置に関するものである。

【0002】

【従来の技術】近年、半導体製造関連装置等の投影露光装置において、極めて高い結像性能が要求されている。従来のこの種の装置には、高度に各種の収差が補正されている投影光学系が搭載されている。通常投影光学系の収差量のチェックは特別なマスクを用いることにより行われていた。この特別なマスクには収差チェック用の専用のパターンが描かれており、この専用のパターンをテスト用基板に露光し、現像後、その露光パターンを顕微鏡等で観察することにより収差量チェックを行う。例えば、球面収差のチェックは異なる複数の線幅のパターンのベストフォーカス位置を求めることにより行われる。具体的には、ステージを光軸方向に順次位置決めして、感光剤が塗布されたテスト用基板を光軸方向に順次移動しつつ複数の線幅のパターンを露光し、現像する。そして、この結果、基板上には投影光学系からの光軸方向の距離に応じた各線幅のパターンが形成される。基板上に形成された各線幅のパターンの各々について、電子顕微鏡等で線幅を測定し、測定したパターンの線幅の実寸法

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と投影光学系の光軸からの距離をプロットする。所定線幅が維持されている基板の位置の中点（所定線幅が維持されている基板位置の最大位置と最小位置との中間点）をベストフォーカスと決定すれば、そのプロットされたデータのカーブより、各線幅のベストフォーカス位置が求まる。ここで、球面収差が発生している場合、各線幅のベストフォーカス位置にずれが生じる。非点収差のチェックは方向の異なるパターンのベストフォーカス位置の差を求めればよい。次にコマ収差のチェックの例を示すと、複数の連続した等しい線幅のマークの両端の線幅の差を見るといった方法がある。

【0003】上記の様な方法により各収差を求め、投影光学系の結像特性を最適化していく。例えば投影光学系の内部のレンズエレメントの間隔等を調整して最終的に各収差を許容値以下とする。ところが、各収差は常に一定ではなく、温度変化、大気圧変化及び照明光を投影光学系が吸収することによる投影光学系の温度上昇により変化し得るものである。特に照明光の吸収による投影光学系の温度変化は投影光学系内部のレンズエレメントに温度分布を生じ、無視し得ない収差変化をもたらす場合がある。この様な場合、露光動作中の収差量を上記の方法でチェックするのは不可能である。

【0004】そこで、従来より露光エネルギーの投影光学系への蓄積量を計算し、蓄積量が一定基準値を越えると露光動作を一時停止し、収差が悪化した所では使用しないという方法が提案されていた。具体的には、あらかじめ発生する収差量と投影光学系に蓄積される熱量との関係や投影光学系の熱吸収特性を求めておく。実露光動作時には、あらかじめ求めておいた熱吸収特性の数値モデルとマスク透過率とシャッター開閉信号とより逐次投影光学系へ蓄積された熱量の計算を行い、発生する収差量を求める計算を行う。収差量が許容値をオーバした時、露光動作を一時中止すれば投影光学系へ蓄積された熱量は減衰していき収差量も許容値以下となり再び露光動作を行うことができる。このような露光方法は例えば特開昭63－291417号公報に開示されている。

【0005】

【発明が解決しようとする課題】上記の如き従来の技術においては、求められた収差量はあくまでも予測値であり、実際の収差発生量がわからない。特に近年においては解像力を増すための技術として、輪帯状の照明、あるいは特開平4－180612号公報や特開平4－180613号公報に開示されているような複数方向からの傾斜照明等が提案され、さらに特公昭62－50811号公報に開示されているような位相シフトマスクも提案されている。これらの技術を使用した場合、投影光学系内部での照明光の強度分布が異なる。このため照明エネルギーは同一でも照明条件あるいはレチクルによって発生する収差量も異なり、収差発生量の予測が困難である。従って従来の収差量を予想する方法では所望の露光動作

に対応ができないという問題点があった。本発明はこの様な従来の問題点に鑑みてなされたもので、実際の収差量の計測を可能とし、結像特性の変動に対応可能な装置を提供することを目的とする。

【0006】

【課題を解決するための手段】上記問題点の解決のために本発明では、光源（1）からの照明光をマスク（R）に照射する照明光学系（6、7、10）と、マスクのパターン（PA）を感光基板（W）上に結像する投影光学系（PL）と、感光基板を保持するとともに投影光学系の光軸（AX）方向及び光軸と垂直な方向に移動可能なステージ（15）とを有する投影露光装置において、ステージ上に設けられ、所定の開口パターンを有する基準部材（19）と；ステージを光軸方向に移動させながら開口パターンをステージ側より照明し、投影光学系を介してマスクに到達しマスクで反射された光を、投影光学系と開口パターンを介して受光する受光手段と；光軸方向に関するステージの位置を計測するステージ位置計測手段と；光電検出手段から得られる信号波形より投影光学系の収差量を求める収差量演算手段とを設けた。

【0007】

【作用】本発明においては、ステージ上に設けられた所定の開口パターンをステージ側から露光光とほぼ等しい波長の光で照明し、この照明光を投影光学系を介してマスクに入射させる。そしてマスクで反射された照明光を投影光学系、開口パターンを介して光電検出器に入射させる。この光電検出器からの光電検出信号の波形を用いて収差量を求める。たのため、テスト基板への露光、現像、測定といった手順を省くことができるとともに専用のパターンをマスク上に設ける必要がないため、実際の測定時においても逐次、収差量の変化を知ることができる。この結果、収差が発生している状態で露光を行い、不良品を出すという不都合はない。

【0008】

【実施例】図1は本発明の一実施例による投影露光装置の概略的な構成を示す平面図である。図において超高圧水銀ランプ等の光源1はレジスト層を感光する波長域の照明光（i線等）ILを発生する。露光用光源としては、水銀ランプ等の輝線の他、KrF、ArFエキシマレーザ等のレーザ光源、あるいは金属蒸気レーザやYAGレーザの高調波を用いても構わない。照明光ILは楕円鏡2で反射してその第2焦点f_0に集光した後、ミラー5及びコリメータレンズ6、フライアイレンズ7に入射する。フライアイレンズの射出側には可変絞り8が設けられており、レチクルの種類やパターンの周期性に応じて照明条件を変更することが可能になっている。この照明条件の変更はモータ9により可変絞り8を駆動することにより実行される。

【0009】また、第2焦点f_0の近傍にはモータ4によって照明光ILの光路の閉鎖、開放を行うシャッター

（例えば4枚羽のロータリーシャッタ）3が配置される。可変絞り8を通過した照明光ILはリレーレンズ12a、12b及びレチクルR上の照明領域を制限する可変ブラインド11、コンデンサーレンズ13を含む光学系10に入射し、ミラー14に到り、ここで、ほぼ垂直に下方に反射された後、レチクルRのパターン領域PAをほぼ均一な照度で照明する。レチクルRはレチクルステージRS上に載置されており、レチクルステージRSはレチクルRをXY方向に微動可能となっている。また、レチクルステージRSは駆動部51によりレチクルRをZ方向（光軸方向）へも微動可能であり、レチクルRと投影光学系PLの距離を変えたり、レチクルRを光軸AXに垂直な平面に対して傾けることができる。パターン領域PAを通過した照明光ILは両側テレセントリックな投影光学系PLに入射し、投影光学系PLはレチクルRの回路パターンの投影像をウェハW上に形成する。ウェハWは表面にレジスト層が形成され、その表面が最良結像面とほぼ一致するようにウェハステージ15上に保持され、回路パターンはウェハW上の1つのショット領域に重合わせて結像投影される。（図1は説明の都合上ウェハW上に結像していない。）ウェハWはウェハホルダ16に真空吸着され、このホルダ16を介してウェハステージ15上に保持されている。ウェハステージ15は投影光学系PLの最良結像面に対し、任意方向に傾斜可能でかつ光軸方向（Z方向）に微動可能であるとともに、ステップ・アンド・リピート方式で2次元方向（X、Y方向）に移動可能に構成されており、ウェハW上の1つのショット領域に対するレチクルRの転写露光が終了すると、次のショット位置までステッピングされる。

【0010】また、図1中には投影光学系PLの最良像面に向けてピンホール、あるいはスリットの像を形成するための結像光束を光軸AXに対して斜め方向より供給する照射光学系17と、その結像光束のウェハWの表面での反射光束をスリットを介して受光する受光光学系18から成る斜入射方式の合焦系（ウェハ位置検出系）が設けられている。この合焦系の構成等については、例えば特開昭60－168112号公報に開示されており、ウェハ表面の結像面に対する方向（Z方向）の位置を検出し、ウェハWと投影光学系PLとの合焦状態を検出するものである。尚、本実施例では設計上の最良結像面が零点基準となるように、予め受光光学系18の内部に設けられた不図示の平行平板ガラス（プレーンパラレル）の角度が調整されて、合焦系のキャリブレーションが行われる。

【0011】次に収差検出系の説明を行う。ウェハステージ15上にはパターン板19が設けられており、パターン板19上には図2に示すように収差検出用の所定の開口パターンが描かれている。ここではパターン板19の表面はウェハWの表面とほぼ同一平面上となるように

パターン板１９が設けられている。ほぼ照明光ＩＬと同一波長領域の光線ＩＬ’は２分岐ファイバー２０、可変絞り２１、リレーレンズ２３ａ、２３ｂ、ミラー２４、コンデンサーレンズ２５を介してウェハステージ１５側（下方）よりパターン板１９を照明する。照明光ＩＬ’は光源１からの照明光ＩＬを分岐してもよいし、照明光ＩＬと同一波長の光を射出する光源を別設してもよい。パターン板１９のパターン開口部より出た光束は投影光学系ＰＬを介してレチクルＲのパターン面ＰＡに結像し、その反射光が再び投影光学系ＰＬを介してパターン板１９上に結像する。パターン板１９に到った光束は再びパターン１９の開口部を通過し、コンデンサーレンズ２５、ミラー２４、リレーレンズ２３ａ、２３ｂ、可変絞り２１及び２分岐ファイバー２０を通り、光電変換素子２６に達する。主制御系２９はモータ２７を制御してウェハステージ１５をＺ方向に移動し、これと同時に主制御系２９内の収差検出系２８は光電変換素子２６からの信号Ｓ３を焦点検出系の受光光学系１８からの信号と同期して受取る。これにより収差検出系２８はウェハステージ１５のＺ方向の位置に対する光電変換素子２６の出力を得る。主制御系２９は可変絞り８を駆動するモータ９や可変絞り２１を駆動するモータ２２の制御も行う。尚、収差検出系２８はＴＴＬ（スルーザレンズ）方式の焦点位置検出（投影光学系ＰＬの結像面検出）に用いることが可能で焦点位置と収差を同時に検出することができる。主制御系２９は駆動部５１の制御の他、装置全体を統括的に制御する。ここで、開口パターンは非点収差を考慮して、図２の様に多方向のパターンの組み合わせとなっている。

【００１２】収差検出系２８により焦点位置が求まる原理を図３を用いて簡単に説明する。図３（ａ）はレチクルＲとパターン板１９とが共役な位置から若干ずれているときのマスクＲで反射され、投影光学系ＰＬを介して再び結像された開口パターン１９の像の光量分布を示す図であり、図３（ｂ）はマスクＲとパターン板１９とが共役な位置にあるとき、マスクＲで反射され投影光学系ＰＬを介して再び結像された開口パターン１９の像の光量分布を示す図であり、図３（ｃ）は基準パターン板１９の一例を示している。図３（ｃ）において１９ａはクロム蒸着膜等による遮光部である。

【００１３】基準パターン板１９とレチクルＲのパターン面とが共役な位置にあるとき、基準パターン板１９の像の強度分布は、図３（ｂ）の分布Ｃａに示すように、基準パターン板１９自体の明暗の分布とほぼ一致し、基準パターン板１９の透過部を介してほぼ大部分の光がウェハステージ１５に戻っていく。一方、基準パターン板１９がレチクルＲのパターン面と共役な面から若干ずれている場合、レチクルＲからの反射光により再結像された基準パターン板１９の像は、図３（ａ）の分布Ｃｂに示すようにコントラストが低下する。この場合、図３（ａ）の分布Ｃｂ中の斜線部は、図３（ｃ）の基準パターン１９の遮光部（非透過部）１９ａに重なり、基準パターン１９を通過していくことができず、光電変換素子２６に達する光量は減少する。

【００１４】図４は光電変換素子２６からの検出信号Ｓ３の出力値を縦軸とし、パターン板１９のＺ座標を横軸とし、開口パターン１９をＺ方向に移動させた場合の光電変換素子２６からの出力値を示す図である。パターン板１９のＺ方向の位置は焦点検出系の受光光学系１８からの出力から求めることができる。図４中で最も光電変換素子２６の出力値Ｓ３が最も大きいとき（ピーク値のとき）のＺ座標ＺａはレチクルＲとパターン板１９とがほぼ共役な位置にあるときを示し、図３（ｂ）の場合に相当する。図４中で光電変換素子２６からの出力値がピーク値から下がっている点にあるときのＺ座標ＺｂはレチクルＲとパターン板１９とが共役な位置から若干ずれている時を示し、図３（ａ）の場合に相当する。

【００１５】以上の様に基準パターン板１９が投影光学系ＰＬの焦点位置に来たとき、光電変換素子２６から出力される検出信号Ｓ３は最大となる。検出信号Ｓ３の信号波形は光束の干渉現象により、例えば図４に示すようにピークの両側で凹状に落ち込む波形となる。次に、結像状態を補正するための補正手段の構成について説明する。本実施例においては、投影光学系ＰＬのレンズエレメントを駆動したり、レンズエレメント間の圧力を変えることにより、結像特性（球面収差、コマ収差、非点収差、像面湾曲等）を補正する構成となっている。このため、投影光学系ＰＬの光学要素の一部が移動可能となっている。さらに、投影光学系ＰＬの光学要素間の圧力を可変とする構成となっている。図５は図１の装置を部分的に説明する図であり、レチクルＲの駆動部と投影光学系ＰＬの光学要素の駆動部と光学要素間の圧力を可変とする機構を示す図である。レチクルＲに最も近いレンズエレメント３３は支持部材３４により固定され、駆動素子３５を介して支持部材３６上に設けられている。支持部材３６は投影光学系ＰＬの鏡筒５２に固定されている。駆動素子３５はそれぞれ１２０°ずつ回転した位置に配置された駆動素子３５ａ、３５ｂ、３５ｃ（図５では３５ａ、３５ｂのみ図示）からなり、各々の駆動素子は駆動素子制御部３８により独立制御可能となっている。尚、図５ではレンズエレメント３３は１つのレンズとして示しているが、３群（或いは２群）のレンズ群からなるレンズエレメントであるものとし、レンズエレメント３３を構成する各々のレンズ群は駆動素子（不図示）により独立に微動可能となっている。

【００１６】また、投影光学系ＰＬの瞳面Ｐ１近傍に近いレンズエレメント４４は支持部材４５により固定され、駆動素子４６を介して支持部材４７上に設けられている。支持部材４７は投影光学系ＰＬの鏡筒５２に固定されている。駆動素子４６はそれぞれ１２０°ずつ回転

した位置に配置された駆動素子46a、46b、46c（図5では46a、46bのみ図示）からなり、各々の駆動素子は駆動素子制御部48により独立制御可能となっている。駆動素子35、46としては、例えば電歪素子，磁歪素子を用い、駆動素子に与える電圧または磁界に応じた駆動素子の変位量は予め求めておくものとする。ここでは図示していないが、駆動素子のヒステリシス性を考慮し、位置検出装置として容量型変位センサ，差動トランス等を駆動素子の近傍に設けることとする。これにより、駆動素子に与える電圧または磁界に対応した駆動素子の位置をモニターできるので、高精度な駆動が可能となる。レンズエレメン33、44の微動はレンズエレメントの間隔を変えたり、レンズエレメントを光軸AXに垂直な平面に対して傾けたり、レンズエレメントを光軸AXに垂直な平面内で移動したりするように行われる。このような光学要素を駆動する構成、動作については特開平4－134813号公報に詳しく開示されている。

【0017】本実施例では駆動素子制御部38によって前述の駆動素子35を制御することにより、レチクルRに近いレンズエレメント33を移動可能となっており、レンズエレメント33はコマ収差、像面湾曲等の結像特性に与える影響が他のレンズエレメントに比べて大きく制御しやすいものを選択してある。また、移動可能なレンズエレメント33を3群構成としているため、他の諸収差の変動を押さえつつレンズエレメントを移動させることにより移動範囲を大きくできる。また、駆動素子制御部48によって前述の駆動素子46を制御することにより、瞳面P1に近いレンズエレメント44を移動可能となっており、レンズエレメント44は球面収差に与える影響が他のレンズエレメントに比べて大きく制御しやすいものを選択してある。

【0018】レンズエレメント37と50とは鏡筒52に固定されており、気圧調整装置39はレンズエレメント33とレンズエレメント37との間のレンズ室内の空気の圧力を調整し、気圧調整装置49はレンズエレメント44とエンズエレメント50との間のレンズ室内の空気の圧力を調整する。このようにレンズエレメント間の空気部の圧力を変えることにより投影光学系の結像特性を変化させて収差等を補正することは特開昭60－78454に開示されている。

【0019】また、瞳面P1の近傍には2枚のシリンドリカルレンズ40、41が設けられており、これらを駆動部42、43により相対的に回転させたり、レンズの間隔を変えたりすることにより非点収差を制御する。シリンドリカルレンズ40、41は互いに直交した方向に配置されており、これらを相対的に回転させることによりX、Y方向での屈折率を変化させる。そしてX、Y成分が互いに打ち消し合うようにこれらのレンズを相対的に回転させて他のレンズエレメントで発生した非点収差

成分を除去する。主制御系29はこれらの駆動素子制御部38、48、駆動部42、43、気圧調整装置39、49を制御する。

【0020】次に前述の可変絞り8及び投影光学系PL内の可変絞り30について、簡単に説明する。照明系の特性を示す数値としては一般に、投影光学系の開口数NAと照明光のコヒーレンシィを表すσ値とが用いられる。図6を参照して開口数とσ値について説明する。図6において、投影光学系PLの瞳面P1、即ちマスクパターンPAのフーリエ変換面には開口絞り30が設けられているため、投影光学系PLのレチクルR側からの光束が通過できる最大の角度θ_R及び投影光学系PLからウェハW（パターン板19）側に落射する光束の最大の角度θ_Wは所定の値に制限されている。投影光学系PLの開口数$_{IL}$はsinθ_Wであり、投影倍率を1／mとすると、sinθ_R＝sinθ_W／mの関係にある。

【0021】

【数1】$\sigma_{IL}=\sin\theta_{IL}/\sin\theta_R=m\cdot\sin\theta_{IL}/\sin\theta_W$

一般に開口数NAが大きい程解像度は向上するが、焦点深度が浅くなる。一方、σ値が小さい程に露光光ILのコヒーレンシィが良くなるため、σ値が小さくなるとパターンのエッジが強調され、σ値が大きいとパターンのエッジがぼけるが、より細いパターンの解像ができるようになる。従って、σ値が変化すると、投影光学系PLの瞳面P1における照度分布が変化する。

【0022】このことは、前述のように照明条件により、投影光学系PL内部の温度分布が変化し、温度上昇によって発生する収差が異なることを意味する。具体的には、回転板8には、図7に示すように、例えば6種類の開口絞り132～137を等角度間隔で形成する。これらの開口絞りの内で、円形開口絞り132及び133はそれぞれ異なる直径の通常の円形の開口部132a及び133aを有し、輪帯開口絞り134は輪帯状の開口部134aを有する。また、複数傾斜照明用の開口絞り135及び136はそれぞれ互いに直交する方向に配置された1対の微小開口部135a，135b及び136a，136bを有し、複数傾斜照明用の開口絞り137は光軸を中心として等距離に配置された4個の微小開口部137a～137dを有する。

【0023】尚、回転板8の絞り135，136，137を使用するときには各開口部からの照明光束のσ値が0．1～0．3程度となるように設定することが望ましい。更に、レチクルパターンの微細度（ピッチ等）に応じて絞り135～137の各々における各開口部の位置を微調整できるように構成しておくことが望ましい。更に、絞り133～137を用いるときはレチクルまたはウェハ上での照度均一性が悪くなり得るのでフライアイレンズ7の各エレメントを細かくする（断面積を小さくする）ことが望ましい。さらに別のインテグレータ（フ

ライアイ型又はロッド型）を追加して２段のインテグレータ構造としても良い。

【００２４】また絞り１３５～１３７の使用時は光量ロスが大きいので、光ファイバー、多面プリズム等の光分割器を用いて、絞り上の各開口部に露光光を導くように構成しておくと良い。また、回転板８の開口絞りの選択基準の一例としては、特に微細パターンに対しては開口絞り１３５，１３６，１３７（この３つの使い分けはレチクルパターンの周期性に応じて選択すれば良い）を用い、線幅が厳しくないときは開口絞り１３２を用い、位相シフトレチクルには例えば開口絞り１３３（又は開口絞り１４１を使用しても良い）を用いる。開口絞り１３５は例えばX方向に配列された周期パターン、開口絞り３６はY方向に配列された周期パターン、開口絞り１３７は２次元パターンに対して有効である。

【００２５】開口絞り１３５、１３６、１３７の開口部の最適位置については特開平４－１８０６１２号公報、特開平４－１８０６１３号公報や特開平４－２２５５１４号公報等に開示されている。例えば、開口絞り１３７は２次元周期パターンに対して有効な開口絞りであり、開口絞り１３７については１つの開口部１３７ａに着目したとき、X方向のパターンによる±１次回折光のいずれか一方とY方向のパターンによる±１次回折光のいずれか一方と０次回折光とが投影光学系ＰＬの瞳面Ｐ１上で光軸から等距離となるように、開口部１３７ａの位置を定める。他の開口部（１３７ｂ～１３７ｄ）についても同様の条件で位置を定めると結局各々の開口部（１３７ａ～１３７ｄ）は光軸から等距離となる位置に定められる。

【００２６】ここで、光電変換素子２６からの信号波形から収差を求める場合、照明光学系１０からの照明光ＩＬとパターン板１９を通過した照明光ＩＬ’とが投影光学系ＰＬを通過する時の２つの光量分布を一致させるため、ファイバー２０からの照明光による投影光学系ＰＬの瞳面Ｐ１における照度分布をフライアイレンズ７から射出した照明光による投影光学系ＰＬの瞳面Ｐ１における照度分布と等しくする必要がある。そこで、例えばファイバー束の合同端２０ｂの近傍に回転板２１を設け、回転板２１に設けられた開口絞りを図７に示す開口絞り（１３２～１３７）と相似な６種類の開口絞りとし、回転板８の開口絞りに合わせて、回転板２１の開口絞りを選択するようにすればよい。

【００２７】次に光電変換素子２６からの信号波形から収差を求める方法について説明する。光電検出信号の波形より、各収差量が求められる原理は以下の様に説明できる。特定パターン線幅の解像を良くするため照明光源のＮＡを小さくした場合（部分コヒーレント照明とした場合）、投影光学系のレンズの中央部に光束がかたよる（集まる）ことになる。マスクパターンがある場合は回折光がレンズの周辺に到達するが、一般に０次以外の回折光の強度は０次回折光よりも弱いのでレンズの中央部に光束が偏るという傾向は変わらない。

【００２８】そこで、投影光学系を構成するレンズにごくわずかの熱吸収が存在した場合、投影光学系に光を照射するとレンズを透過する光量に従って発熱が起こる。レンズが発熱した場合、膨張とともに、多くの場合屈折率が増加する（ただし、発熱による減少の場合もある）。つまり、発熱により正のパワー（屈折力）を持つ凸レンズではレンズ中央部の変形と分布屈折率レンズの効果により、レンズ中央部のパワーが周辺部に比べて増大する。図８にこの様子を示し、図８（ａ）は球面収差がない状態を示し、図８（ｂ）は球面収差を過剰補正した状態（球面収差が発生している状態）を示している。図８（ａ）のように初期状態で球面収差が補正されていた場合、光の照射後には図８（ｂ）の斜線で示すようにレンズ３２の中央部のパワーが増大し、球面収差をMだけ過剰補正した状態となるため焦点位置が変動する（ピントがぼける）。

【００２９】図９は光電検出器２６からの出力信号Ｓ３を示す図であり、図４と同様に縦軸は信号強度を示し、横軸はパターン板１９のＺ方向の位置を示す。図９（ａ）は球面収差がない場合の出力信号Ｓ３を示し、図９（ｂ）は球面収差が発生している場合の出力信号Ｓ３を示している。この状態でフォーカス検出装置による信号検出を行った場合、図９（ｂ）に示す様に光軸方向に沿って広がった信号が得られることになる。球面収差のない状態では光束径は光軸に沿って対称な直径となる。図９（ａ）に示された信号波形の半値幅はW_1であり、半値幅W_1の中心とピーク値でのＺ位置Z_0は一致している。すなわち、図９（ａ）の信号波形はピーク値に関して対称な信号波形となっている。

【００３０】これに対して、図９（ｂ）では球面収差過剰補正により最小錯乱円位置（図９（ｂ）ではZ_1）を基準としてその前後での光束径は光軸にそって非対称な直径となる。従って図９（ｂ）に示した様に信号光量の分布はZ_1に関して非対称となる。以上が光照射によりレンズが非対称に変形及び分布屈折率を持ち、フォーカス検出信号が歪むプロセスである。なおレンズには凹レンズも含まれるが、全体として凸レンズなので以上の説明が定性的に当てはまる。その際、発生する（過剰補正による）球面収差量に従って信号の半値幅w_2は半値幅W_1と比べて大きくなるので、半値幅w_2を測定して球面収差量を測定することができる。また、信号の非対称性も球面収差量に従って増大するため、信号の非対称性から球面収差量を測定することも可能である。具体的には信号波形の左側のボトム値I_0と信号波形のピーク値P_0を挟んで右側のボトム値I_1との出力差I_2を測定することによっても球面収差の測定が可能である。また、ボトム値はボトム値I_0、I_1だけでなく高次成分として複数のボトム値がピーク値P_0を挟んで左右に現

れる。この左右のボトム値を複数組に渡って比較することにより高精度に球面収差量を測定することができる。尚、信号の半値幅Wの変化と球面収差の発生量の関係、またはボトム値の差と球面収差の発生量の関係とは予め試し焼き等を行うことより求められている。この関係は入力手段５３により主制御系２９に入力され、主制御系２９内のメモリに記憶されているものとする。また像面湾曲についても図２に示すような多方向の開口パターン１９ａを用いて像面内のピント位置を測定することにより求める。

【００３１】以上のケースでは投影レンズに軸対称に光束が当たった場合について説明した。しかし、マスクに一方向のパターンがある場合等は回折光が軸対称ではなく非対称に発生することになる。従って照射によるレンズの変形が軸に非対称に起こる場合が考えられる。つまり照射により非点収差（非点隔差）が生じる。この場合投影パターン板１９のパターン１９ａを同一方向に揃え、かつ、その方向を異なった少なくとも２つの方向（投影光学系の光軸を中心として放射方向とそれに垂直な方向）でフォーカス位置計測を行う様にする。すると非点隔差がある場合は図７に示したピーク位置Z_0の値が各々の方向で異なり、その差を計測することで非点隔差の計測が行える。

【００３２】また、以上の例では球面収差、像面湾曲、非点収差について説明したが、その他コマ収差等も収差検出系により検出できる。つまり、コマ収差により光軸方向のピント位置や検出信号が広がりを持つことを検出すればよい。具体的には図１０に示すように開口パターン１９ａを投影光学系ＰＬの光軸ＡＸを中心として放射状のパターン（Ｓ像）とそれに垂直なパターン（Ｍ像）との２つの方向を有するパターンとする。そして、各々のパターンから得られる信号の非対称成分を比較することによりコマ収差を計測することができる。図１１は図１０に示すパターンから得られる信号波形を示しており、ここでは図１１（ａ）は放射方向のパターン（Ｓ像）から得られる信号を示しており、図１１（ｂ）は放射方向に垂直な方向のパターン（Ｍ像）から得られる信号を示している。図１１ではコマ収差のために放射方向成分（Ｓ像）が非対称となっている場合を示しており、収差検出系２８によりこれらの２つの信号の非対称成分を比較してコマ収差量を計測する。非対称性の検出は図９を使って説明した球面収差の検出の場合と同様に半値幅Ｗを使って、２つの信号の半値幅W_1とW_2と比較したり、ピーク値を挟んだ２つのボトム値を比較する等により求めればよい。非対称成分の差とコマ収差量との関係とは予め試し焼き等を行うことより求められている。この関係は入力手段５３により主制御系２９に入力され、主制御系２９内のメモリに記憶されているものとする。

【００３３】尚、球面収差やコマ収差を計測する際、パターン１９ａの異なった２方向での計測は図１に示すフォーカス計測系を複数備えてもよいし、パターン１９ａに異なった方向のマークを設けておき、それらを絞り等で切り換えて選択する方法を取ってもよい。次に本実施例における球面収差、コマ収差等の投影光学系ＰＬの結像特性の計測方法について述べる。基準部材１９上の開口１９ａの中心が投影光学系の光軸ＡＸ上に来るようにウェハステージ１５をモータ２７で移動する。このとき同時にモータ２７を駆動してウェハステージ１５を投影光学系ＰＬの設計上の最良焦点位置（最良結像面）と思われる位置から予想される焦点変動量（結像特性の変動量）の数倍程度下げるか、もしくは上げるかする。これは、例えば焦点深度（±ＤＯＦ）の２倍程度（２・ＤＯＦ）下げるか、もしくは上げるかしてもよい。また、同時に開口１９及び投影光学系ＰＬを介してレチクルＲの裏面（パターン面）を照明する。レチクルＲから反射した照明光は再び投影光学系ＰＬ、開口１９を通った後、レンズ２５、ミラー２４、レンズ２３、光ファイバ２０を介して光電検出器２６に入射する。その後この状態でウェハステージ１５を、上方（あるいは下方）に前述した予想される焦点変動量の２倍程度走査する。このとき収差検出部２８は、光電検出器２６の出力と合焦系の受光光学系１８の出力を同時に、例えばウェハステージ１５の単位移動量（例えば０．０２μm）ごとにサンプリングしてＡ／Ｄ変換し、図４に示すような関係を得る。そして、前述の如く光電変換素子２６からの信号波形に基づいて、その対称性等から収差を計測する。

【００３４】次に本実施例による投影光学系ＰＬの収差の補正方法について説明する。前述の様にして収差量を検出した場合、投影レンズを調整する等により収差の補正を行うことができる。

〔球面収差の補正〕球面収差の補正方法について説明する。球面収差の補正は投影光学系ＰＬの瞳Ｐ２付近のレンズエレメント４４、５０（図５）のレンズ間隔を変えることにより行われる。また、レンズエレメント４４、５０間のレンズ室内の空気の圧力を気圧調節装置４９により変えることにより収差補正を行うようにしてもよい。

〔コマ収差、像面湾曲の補正〕コマ収差や像面湾曲の補正は瞳Ｐ２から離れたレンズの間隔を変えることにより行う。本実施例ではレンズエレメント３３を移動、傾斜することにより収差補正を行う。また、コマ収差の補正はレンズエレメント３３と３７との間のレンズ室内の空気の圧力を気圧調整装置３９により行うようにしてもよい。

〔非点収差の補正〕非点収差の補正はレンズ内に設けられた２枚のシリンドリカルレンズ４０、４１を相対的に回転させることにより行う。また、２枚のシリンドリカルレンズの間隔を変えるようにしてもよい。

【００３５】以上、各々の収差補正は他の収差に影響が

少ないレンズエレメントを選択して行われている。また、これらの収差の計測と補正は各照明条件の変更と連動して行うようにする。ここで、もし、投影レンズが複数あるいはある波長帯で色消されている場合、図1の合焦系（照射光学系17）から複数の波長を照射可能とし、複数の波長を使った計測を各々独立に行い、光電変換素子26からの信号基づいて上述した諸収差を計測することが可能である。その場合、光源部にバントパスフィルターを挿入し、それをそれぞれ複数波長を透過するように交換する。

【0036】また、レンズエレメント33、44の駆動により、像面が上下動してしまう可能性も考えられるが、この変化量に応じて合焦系の受光光学系18からの出力値にオフセットを与えてやればウエハWが常に最良像面にセットされる。次に収差検出系28からの結果に基づき、露光を中断させる露光シーケンスについて説明する。

【0037】光電変換素子26からの信号の半値幅w_2がある程度以上に大きくなると、結像状態が悪化するので、あらかじめw_2の上限を定めておき、それを越えた場合には露光動作を中断するようにすることも考えられる。前述のように投影光学系PLの照明光の吸収により収差条件が悪化していく。このため、露光動作中、例えばウェハ交換時に収差測定手段により収差をチェックし、あらかじめ実験あるいはシュミレーションで求めた許容値に対して越えているか否かの判定を行う。もちろんこのとき焦点位置のキャリブレーションを同時に行うのが望ましい。許容値を越えている場合、収差検出系28は主制御系29に警告を発生し、主制御系29は露光動作を中止する。この状態で定期的（例えば30sec毎）に収差の測定を行い許容値を越えているか否かの判定を行う。露光動作の中断により投影光学系PLに蓄積された熱量が外部に放出され、許容値以下となった順に、収差検出系28は露光OKの信号を主制御系29に送り、メインコントローラは再び露光動作を開始する。上記の許容値は露光を行うレチクルパターンの線幅、パターン種等で異なってくるため、条件を予め入力手段53により主制御系29に入力し、許容条件を可変にすることも考えられる。又、収差の計測間隔は必ずしも一定間隔毎に限定されるものではなく、照明光ILの照射直後は計測間隔を長くし、照射時間が長くなるにしたがって計測間隔を短くする。また、パターン19を交換可能とし、実露光パターンに一致させてもよい。

【0038】次に、収差検出系により求まる焦点位置のキャリブレーションの補正を行う方法について説明を行う。前記の様に基準パターン板19を用いて焦点位置計測を行うことができる。通常パターン板19のパターンは実際に露光する線幅と一致させているが、露光するパターンは大小様々で必ずしも一致しているとは限らない。この場合に照明光吸収によって球面収差が発生すると線幅により焦点位置が異なり実露光パターンの焦点位置を焦点位置計測の結果が一致しないという問題がある。ここで、露光線幅と球面収差の量がわかれば補正が可能である。線幅に関しては、例えばキーボード等から入力する方法、あるいはレチクルバーコード等で書き込み、読み取る方法が考えられる。球面収差と焦点位置ずれ量に関しては予め測定、あるいはシュミレーションにより関係を求めておき、テーブルあるいは数式の形で記憶しておけばよい。あるいは、球面収差量が焦点検出へ及ぼす影響が充分無視できる許容値を設けておき、許容値以上の場合は焦点位置計測を行わず、例えば露光動作を中断して投影光学系が充分冷却されるのを待つ方法も考えられる。

【0039】このように、投影光学系PLの収差を光電変換素子26からの信号波形に基づいて実際に計測できるので、特別なマスクを用いてパターンを露光する等の手間がかからず、実際の装置使用時において簡単に収差量がわかる。この実測した収差に基づいて、収差発生時の露光動作の中止、収差量による焦点検出系の誤差補正、あるいは収差のリアルタイムの補正等を行うことができる。

【0040】前述の実施例では図5で説明したようにレンズエレメント間の空気室の圧力を変える機構39、49とレンズエレメントの間隔を変える機構38、48、42、43とを有することとしたが、全ての収差補正機構を備える必要はない。例えば圧力を変える機構39、49かレンズエレメントの間隔を変える機構38、48、42、43のいずれか一方を有するようにしてもよい。また、特定の収差補正に対してはこれらの一部のみを備えるだけでも有効である。

【0041】

【効果】以上のように本発明によれば、収差量を実測できるため、収差を補正した状態で露光したり、収差に応じた露光動作を行うことができる。また、収差量を実測できるため、位相シフトレチクルや複数傾斜照明等の発生する収差量が予測できない場合でも、発生する収差に応じた露光が可能となる。

【図面の簡単な説明】

【図1】本発明の一実施例による投影露光装置の概略を示す図である。

【図2】図1の装置による基準パターン板に設けられた開口パターンを示す図である。

【図3】図2の開口パターンを使って焦点位置が求まる原理を説明する図である。

【図4】光電変換素子26からの出力信号と開口パターンのZ位置との関係を示す図である。

【図5】図1の装置の収差補正手段を部分的に示す図である。

【図6】照明条件の違いにより収差量が異なることを説明する図である。

【図7】照明条件変更のための開口絞りを示す図である。

【図8】　球面収差の発生状態を説明する図である。

【図9】（a）収差がない状態の光電変換素子２６からの信号波形を示す図である。

（b）球面収差がある状態の光電変換素子２６からの信号波形を示す図である。

【図１０】　コマ収差を計測するのに使用する開口パターンを説明する図である。

【図１１】（a）Ｓ像でコマ収差がある状態の光電変換素子２６からの信号波形を示す図である。

（b）Ｍ像でコマ収差がない状態の光電変換素子２６からの信号波形を示す図である。

【符号の説明】

8、２１…回転板

１５…ウェハステージ

１７…照射光学系

１８…受光光学系

１９…パターン板

１９ａ…開口パターン

２０…光ファイバー

２６…光電変換素子

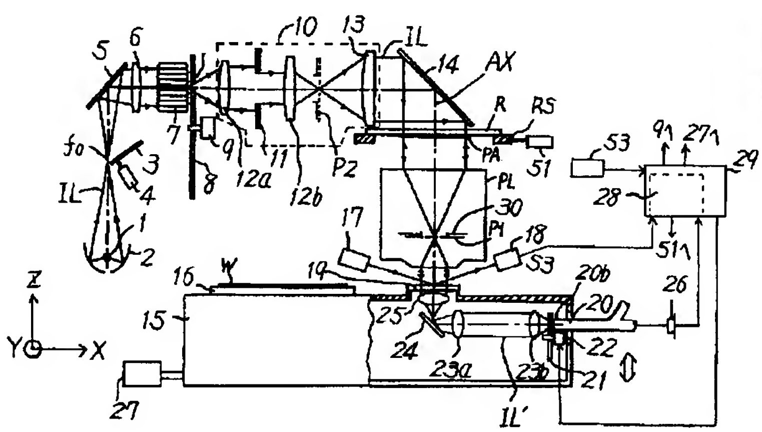
２８…収差検出系

２９…主制御系

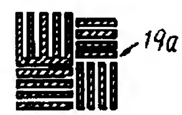
R…レチクル

W…ウェハ

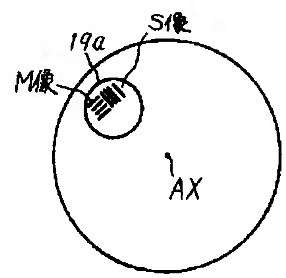
【図1】



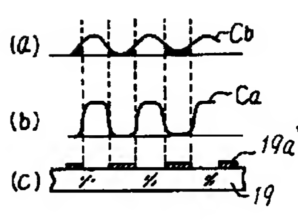
【図2】



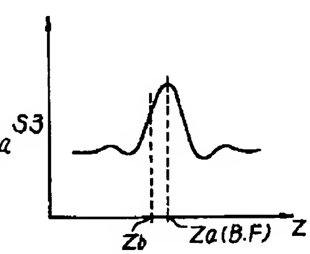
【図１０】



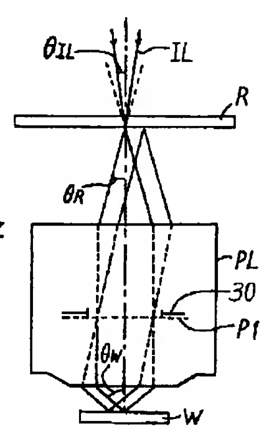
【図3】



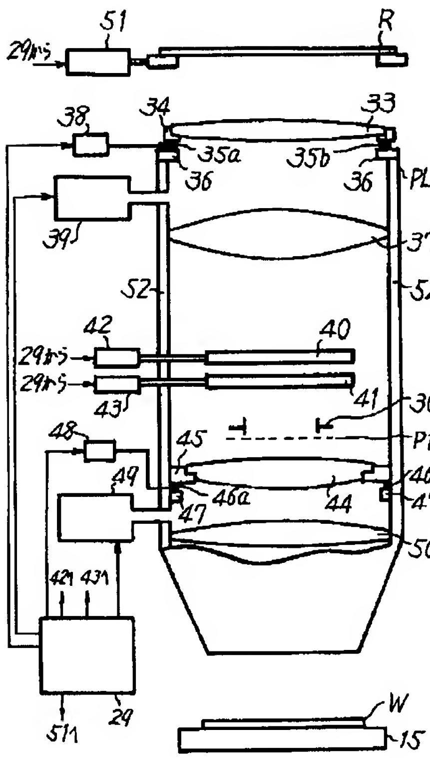
【図4】



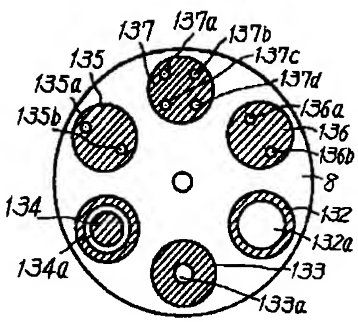
【図6】



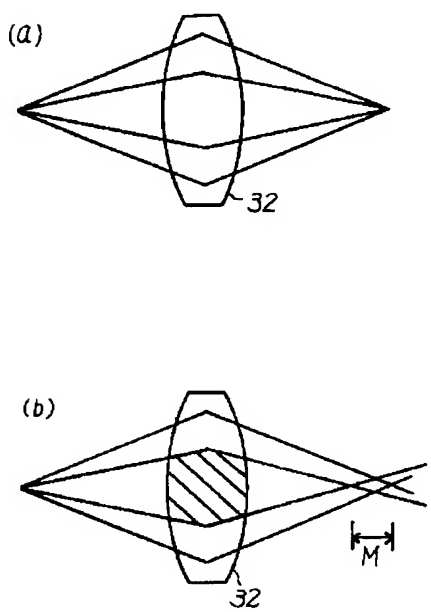
【図5】


51
R
29から
38
34
33
35a
35b
36
36
PL
39
37
52
52
42
40
29から
29から
41
30
43
48
45
P1
49
46b
46a
44
47
47
50
42へ
43へ
51へ
29
W
15

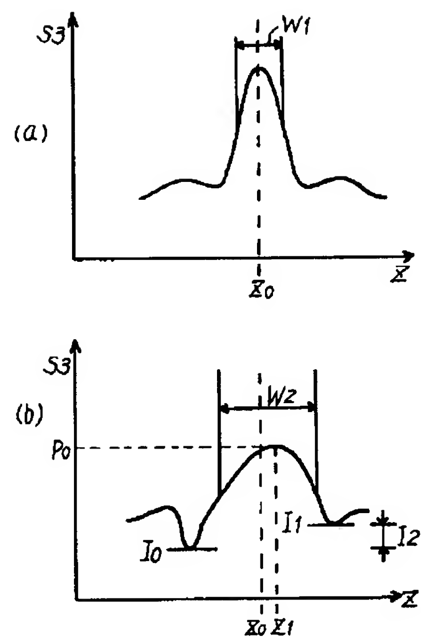
【図7】


137
137a
137b
137c
135
137d
135a
136a
135b
136
136b
8
134
132
132a
134a
133
133a

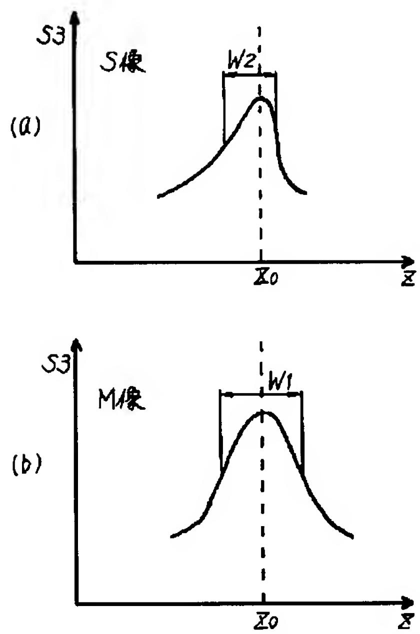
【図8】


(a)
32
(b)
M
32

【図9】


S3
W1
(a)
Z
Z0
S3
(b)
W2
P0
I1
I2
I0
Z
Z0 Z1

【図１１】



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